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USEFUL INFORMATION

FOR

COTTON MANUFACTURERS.

Compiled and Issued

by

STUART W. CRAMER,

Mill Architect and Engineer.

Contractor for

Cotton Mill Machinery

and Equipment.

MAIN OFFICE:
Trust Building,
Charlotte, N. C.

BRANCH OFFICE:
Equitable Building,
Atlanta, Ga.

SECOND EDITION.

(Complete in Three Volumes.)

VOLUME II.

1904.

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SET NO. 831

Bradford Dunbar Textile School

Limited Edition.

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PRINTERS,
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ANNOUNCEMENT.

The above cut illustrates the **Trust Building** just completed at Charlotte, N. C., in which **our offices** are located on the **first floor**.

Our new **draughting rooms** on the **top floor** of this building afford us ample room, light, and other facilities for the proper carrying on of this department of our business, the extent and importance of which will be realized when we call attention to the fact that we have made plans and specifications for over one hundred Southern cotton mills and have installed in them complete outfits of machinery and equipment, not to mention the additional detailed draughting that has been required in connection with the machinery and equipment that we have furnished to practically as many more mills designed by other engineers or by the mill officers themselves

We also call attention to our **Branch Office** in the **Equitable Building, Atlanta, Georgia**.

Our customers and friends are cordially tendered the use of our offices as headquarters when in either Charlotte or Atlanta.

STUART W. CRAMER,
Agent for
THE WHITIN MACHINE WORKS,
WOONSOCKET MACHINE AND PRESS COMPANY,
KITSON MACHINE COMPANY,
ETC., ETC.

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The Textile Machinery ordinarily installed in a yarn or cloth mill on plain work.

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Appendix.

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Index:

An Alphabetical Index for all three volumes.

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SECTION II.

Sundry and Miscellaneous Equipment and Power Plants.

JONES & LAUGHLIN
SHAFTING, PULLEYS, HANGERS, ETC.

Cold-Rolled Shafting.

From Prof. R. H. Thurston's Report on Cold-Rolled Iron and Steel.

General Conclusions.

(1). The process of **cold-rolling** produces a very marked change in the physical properties of the iron or steel thus treated.

(*a*) It increases the tenacity from 25 to 40 per cent. and the resistance to transverse stress from 50 to 80 per cent.

(*b*) It elevates the elastic limits under both tensile and transverse stresses, from 80 to 125 per cent.

(*c*) The modulus of elastic resilience is elevated from 300 to 400 per cent. The elastic resilience to transverse stress is augmented from 150 to 425 per cent.

(2). **Cold-rolling** also improves the metal in other respects:

(*a*) It gives the iron or steel a smooth, bright surface, absolutely free from the scale of black oxide unavoidably left when hot-rolled.

(*b*) It is made exactly to gauge, and for many purposes requires no further preparation.

(*c*) In working the metal, the wear and tear of the tools are less than with hot-rolled iron, thus saving labor and expense in fitting.

(*d*) The **cold-rolled** iron or steel resists stresses much more uniformly than does the untreated metal. Irregularities of resistance exhibited by the latter do not appear in the

J. & L. Shafting, Continued.

former; this is more particularly true for transverse stress, as is shown by the smoothness of the strain-diagrams produced by the cold-rolled bars.

(*e*) This treatment of iron or steel produces a very important improvement in uniformity of structure, the **cold-rolled** iron or steel excelling common iron or steel in its uniformity of density from surface to center, as well as in its uniformity of strength from outside to the middle of the bar.

(3). This great increase of strength, stiffness, elasticity, and resilience is obtained at the expense of some ductility, which diminishes as the tenacity increases. The modulus of ultimate resilience of the cold-rolled metal is, however, above 50 per cent. of that of the untreated metal.

Cold-rolled iron or steel thus greatly excels common iron or steel in all cases where the metal is to sustain maximum loads without permanent set or distortion.

(4). We conclude, that as a material of construction, **cold-rolled** iron or steel has many peculiar advantages; that it is suitable for all constructions not exposed to high temperatures; that it is especially suitable for all purposes demanding a high elastic limit and great shock-resisting power without permanent distortion; that the process improves the metal throughout—its benefits, as has been seen, reaching the center of the bar, and rendering the whole much more homogeneous and uniform than common iron or steel.

The tables of summaries will be found particularly convenient, as exhibiting most concisely all data obtained. The table of working and breaking loads [see Report on page 322] will be of especial value for many cases of practical application.

Very respectfully,
R. H. THURSTON.

J. & L. Shafting, Continued.

Determination of the Effect of Cold-Rolling upon the Inner Portion of the Bar

Tests made by Prof. Thurston at the Mechanical Laboratory, Department of Engineering, Stevens Institute of Technology. Specimens were turned to their respective diameters from bars 2 inches in diameter.

COLD-ROLLED IRON.

Lab. No.	Diam. In.	Elastic Limit.	Modulus of Rupture per sq. inch of		Percentage of Extension.	Percentage of Reduction of area at fracture.
			Orig'l Sect'n.	Fract'd Sect'n.		
1168*	1¾	63,900	66,900	94,800	6.00	29.44
1169	1½	56,600	68,500	95,500	7.65	28.30
1170	1	56,700	60,600	86,200	6.55	31.12
1105B	3/4	56,600	65,640	93,000	9.00	29.66
1105C	5/8	55,400	66,650	90,600	9.22	26.47
1105D	1/2	56,000	66,200	91,600	8.14	27.76
1105E	3/8	54,300	63,400	99,000	7 29	28.89
1105F	1/4	50,900	64,660	91,800	3.43	29.60

HOT-ROLLED IRON.

1171	1 3/4	30,900	48,700	83,100	30.00	41.38
1172	1½	23,500	49,500	82 700	25.70	40.18
1173*	1	26,000	47,900	78,700	21.30	39 14
1104B	¾	23,800	49,330	79,400	21.57	37.85
1104C	5/8	24,100	50,520	90,100	24.57	43 94
1104D	½	23,900	50,980	93,600	18 57	40 42
1104E	3/8	20,800	52,540	97,700	20 57	46.24
1104F	1/4	22,400	42,980	78,400	16.93	47.28

*Broke outside of the initial marks.

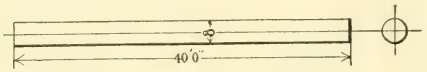
J. & L. Shafting, Continued.

Large Forged Shafts.

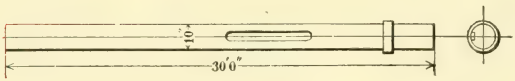
Large shafts forged at short notice from Open Hearth Steel of any diameter up to 20 inches.

Head Shafts, Crank Shafts, Etc.

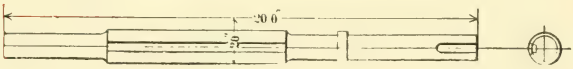
The following cuts illustrate the terms used to designate special work on heavy shafts:



Plain Shaft.



Shaft Collared and Key-Seated for Pulley.



Shaft Bossed, Collared and Key-Seated for Pulley and Coupling.

Key-Seating.

For many purposes long Key-Seats in Shafts are required. Many thousand Cold-Rolled Shafts have been key-seated their entire length, and in *no instance* have they failed to show their superiority over Turned Shafts key-seated.

J. & L. Shafting, Continued.

Table for Laying Out Shafting.

For Ring-Oiling Ball and Socket Hangers and Pillow Blocks.

Diameter of Shaft.	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2
Length of Bearings. 4 Dia.												10	10
Length of Bearings. 5 Dia.	6 1/4	6 3/4	6 1/4	7 1/2	7 1/2	8 3/4	8 3/4	10	10	11 1/4	11 1/4	12 1/2	12 1/2
Length of Coupling.	3 1/2	3 15/16	4 3/8	4 13/16	5 1/4	5 11/16	6 1/8	6 9/16	7	7 7/16	7 7/8	8 5/16	8 3/4
B.	6	6 3/4	7 1/2	8 1/4	9	9 3/4	10 1/2	11 1/4	12	12 3/4	13 1/2	14 1/4	15
E.	1 3/4	1 31/32	2 1/16	2 5/32	2 5/8	2 27/32	3 1/16	3 9/32	3 1/2	3 23/32	3 15/16	4 5/32	4 3/8

For Ring-Oiling Rigid Pillow Blocks.

Length of Bearings.	4 3/4	4 3/8	4 3/8	5 1/4	5 1/4	6 1/8	6 1/8	7	7	7 7/8	7 7/8	8 3/4	8 3/4
B.	5 3/4	6 1/4	6 1/2	7 1/2	8	8 3/4	9 1/4	10	10 1/2	11 1/2	11 3/4	12 3/4	13 1/4

Where Shafts of different diameters are to be coupled, use Reducing Coupling.
For Collins Couplings the difference in diameters should not exceed 1/2″; for Flange Couplings, 1″. Where the difference exceeds these figures the larger shaft must be turned down at the end.

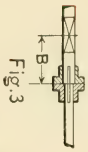


Fig. 3

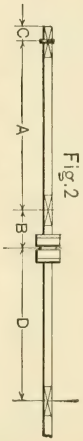


Fig. 2

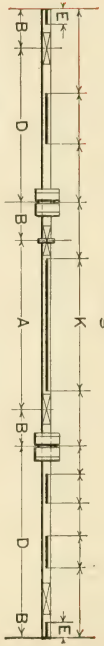


Fig. 1

Table for Laying Out Shafting. Concluded.

For Ring-Oiling Ball and Socket Hangers and Pillow Blocks.

2 5/8	2 3/4	2 7/8	3	3 1/4	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/2	6	6 1/2	7	7 1/2	8	9
11	11	12	12	13	14	15	16	17	18	19	20	22	24	26	28	30	32	36
13 3/4	13 3/4	15	15	16 1/4	17 1/2	18 3/4	20	21 1/4	22 1/2	23 3/4	25	27 1/2	30	32 1/2	35	37 1/2	40	45
9 3/16	9 5/8	10 1/16	10 1/2	11 3/8	12 1/4	13 1/8	14	14 7/8	15 3/4	16 5/8	15 3/4	15 3/4	18	19 1/2	21	21	24	25 1/4
15 3/4	16 1/2	17 1/4	18	19 1/2	21	22 1/2	24	25 1/2	27	28 1/2	28 1/4	29 1/2	33	35 3/4	38 1/2	39 3/4	44	47 3/4
4 17/32	4 13/16	5 1/32	5 1/4	5 11/16	6 1/8	6 9/16	7	7 7/16	7 7/8	8 5/16	7 7/8	7 7/8	9	9 3/4	10 1/2	10 1/2	12	12 3/4

For Ring-Oiling Rigid Pillow Blocks.

9 5/8	9 5/8	10 1/2	10 1/2	11 3/8	12 1/4	13 1/8	14	14 7/8	15 3/4	17 1/2	17 1/2	19 1/4	21	22 3/4	24 1/2	26 1/4	28	31 1/2
14	14 1/2	15 1/4	15 3/4	17	18 1/2	19 3/4	21	22 1/4	23 3/4	25 1/8	24 1/2	25 1/2	28 1/2	31	33 1/4	34 1/4	38	41

Values of "B" can be found from the table for shafts of different diameters. Then the length of middle shaft Fig. 1=A+2B. Length of end shafts=B+D. In Fig. 2, "C"=½ length of bearing. Then length of shaft=C+A+B.

Keyseats should be located as indicated in Fig. 1.

The length of "K" may be K=A—(L+2″) where L=length of bearings.

First shaft to be collared in one bearing as shown.
Flange Couplings may be used from 1″ to 12″ inclusive.
Collins Couplings, from 1″ to 4 3/4″ inclusive.

Note:—The figures in the above table are condensed for convenience; the same marginal headings apply as those in the table on the preceding page.

J. & L. Shafting, Continued.

Transmission of Power by Shafting.

(Notes by J. B. Francis, C. E.)

"Shafts for transmitting power are subject to two forces, viz.—transverse strain and torsion.

"In shafts of wrought iron or steel, in which bearings are not very near to each other, a transverse strain, too small for fracture, will produce sensible deflection; if this is too great it will produce sensible irregularities in the motion, and tend towards the rapid destruction of the shaft and its bearings. This limits the distance between the bearings, as the weight of the shaft itself will produce an inadmissible amount of deflection whenever this distance exceeds a certain amount, which varies with the material and diameter of the shaft.

"In factories power is taken off from the lines of shafting at many points by pulleys and belts, by means of which the machinery is operated.

"When the machines to be driven are below the shaft, there is a transverse strain on the shaft, due to the weight of the pulley and tension of the belt, which is, in addition to the transverse strain, due to the weight of the shaft itself. Sometimes the power is taken off horizontally on one side, in which case the tension of the belt produces a horizontal transverse strain, and the weight of the pulley acts with the weight of the shaft to produce a vertical transverse strain. Frequently the machinery to be driven is placed above the floor to which the shaft is hung in the story below; in this case the transverse strain produced by the tension of the belt, is in the opposite direction to that produced by the weight of the pulley and shaft.

"Sometimes the power is taken off in *all* these directions from the part of a shaft between two adjacent bearings.

"To transmit the same power, the necessary tension of a belt diminishes in proportion to its velocity, consequently, with pulleys of the same diameter, the transverse strain will diminish in the same ratio as the velocity of the shaft increases.

"In cotton and woolen factories with wooden floors, the bearings are usually hung to the beams, which are usually 8 feet apart; and a minimum size of shafting is adopted for the different classes of machinery which has been determined by experience as the least that will withstand the transverse strain. This minimum is adopted independently of the size

J. & L. Shafting, Continued.

required to withstand the torsional strain due to the power transmitted ; if this requires a larger diameter than the minimum, the larger diameter is, of course, adopted.

"In some of the large cotton factories in this neighborhood (Lowell, Mass.), in which the bearings are about 8 feet apart, a minimum diameter of 1 7-8 inch was formerly adopted. In some mills this is still retained ; in others 2 1-8 and 2 3-16 have been substituted. In the same mills the minimum size of shafts driving spinning machinery is from 2 1-8 to 2 11-16 inches."

In very long lines of small shafting fly-wheels are put on at intervals, to diminish the vibratory action due to the irregularities in the torsional strain.

Mr. Francis gives the following :

Table of the Greatest Admissible Distances Between the Bearings of Continuous Shafts, Subject to no Transverse Strain Except from their Own Weight.

Diam. of Shaft in inches.	Distance Between Bearings in Feet.	
	Wrought Iron.	Steel.
2	15.46	15.89
3	17.70	18.19
4	19.48	20 02
5	20 99	21 57
6	22.30	22 92
7	23 48	24.13
8	24.55	25.23
9	25.53	26.24

"In practice, long shafts are scarcely ever entirely free from transverse strains ; however, in the parts of long lines, which have no pulleys or gears with the couplings near the bearings, the intervals between the bearings may approach the distances given in the preceding table. Near the extremities of a line the distances between the bearings should be less than are given in the preceding table. The last space should not exceed sixty per cent of these given, the deflection in that space being much greater than in other parts of the line In shafts moving with high velocities it will usually be necessary to shorten the distances between the bearings in order to obtain sufficient bearing surface to prevent heating."

J. & L. Shafting, Continued.

Horse Power of Shafting.

The torsional strength of shafts, or their resistance to breaking by twisting, is proportional to the cube of their diameter. Their stiffness, or resistance to bending, is proportional to the fourth power of their diameters, and varies inversely in proportion to their load and also to the cube of the length of their spans or "bay."

Receiving and transmitting pulleys should always be placed as close to bearings as possible; and it is good practice to frame short "headers" between the main tie-beams of a mill so as to support the main receivers, carried by the head shafts with a bearing close to each side as is contemplated in the formulæ. But if it is preferred, or necessary, for the shaft to span the full width of the "bay" without intermediate bearings, or for the pulley to be placed away from the bearings towards, or at the middle of the bay, the size of the shaft must be largely increased to secure the stiffness necessary to support the load without undue deflection. Shafts may not deflect more than 1-80 of an inch to each foot of clear length with safety.

To find the diameter of shaft necessary to carry safely the main pulley at the centre of a bay; the following table is practically correct and safe:

Diam. of Shaft given by the formulæ for head shafts.	Diam. of shaft necessary to carry the load at the centre of a bay which is from centre to centre of bearings.							
	2½ ft.	3 ft.	3½ ft.	4 ft.	5 ft.	6 ft.	8 ft.	10 ft.
Inches.	In.	In.	In.	In.	In.	In.	In.	In.
2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3
2 1/2	2 1/2	2 5/8	2 3/4	2 7/8	3	3 1/8	3 3/8	3 5/8
3	3	3 1/8	3 1/4	3 3/8	3 1/2	3 3/4	4	4 1/4
3 1/2		3 1/2	3 5/8	3 3/4	4	4 1/4	4 1/2	4 3/4
4		4	4 1/8	4 1/4	4 1/2	4 3/4	5 1/8	5 3/8
4 1/2			4 1/2	4 5/8	4 7/8	5 1/8	5 1/2	5 7/8
5			5	5 1/8	5 3/8	5 5/8	6	6 1/2
5 1/2				5 1/2	5 3/4	6	6 1/2	6 7/8
6				6	6 3/8	6 5/8	7 1/8	7 1/2

The shaft in a line which carries the receiving pulley, or which carries a transmitting pulley to drive another line, should always be considered a "head shaft," and should be of the size given by the rules for shafts carrying main pulleys or gears.

J. & L. Shafting, Continued.

Horse Power of Turned Iron Shafting.

As Prime Mover or Head Shaft carrying Main Driving Pulley or Gear, well supported by Bearings.

Diam. of Shaft	Number of Revolutions per Minute.										
	100	125	150	175	200	225	250	275	300	325	350
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
2	6.4	8	9.6	11.2	12.8	14.4	16	17.6	19.2	21	22
2¼	8.1	10	12	14	16	18	20	22	24	26	28
2½	12.5	15	18	22	25	28	31	34	37	40	43
2¾	16	20	24	28	32	36	40	44	48	52	56
3	20	25	30	35	40	45	50	55	60	65	70
3¼	27	34	40	47	54	61	67	74	81	88	95
3½	34	42	51	59	68	76	85	93	102	110	118
3¾	42	52	63	73	84	94	105	115	126	136	146
4	51	64	76	89	102	115	127	140	153	165	177
4½	72	90	108	126	144	162	180	198	216	234	250
5	100	125	150	175	200	225	250	275	300	325	350
5½	133	166	199	233	266	299	333	366	400	433	466
6	173	216	259	302	345	388	431	474	517	560	603

As Second Movers or Line Shafting, Bearings 8 Feet Apart.

Diam. of Shaft.	Number of Revolutions per Minute.										
	100	125	150	175	200	225	250	275	300	325	350
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
1¾	6	7.4	8.9	10.4	11.9	13.4	14.9	16.4	17.9	19.4	20.9
1⅞	7.3	9.1	10.9	12.7	14.5	16.3	18.2	20	21.8	23.6	25.4
2	8.9	11.1	13.3	15.5	17.7	20	22.2	24.4	26.6	28.8	31
2⅛	10.6	13.2	15.9	18.5	21.2	23.8	26.5	29.1	31.8	34.4	37
2¼	12.6	15.8	19	22	25	28	31	35	38	41	44
2⅜	15	18	22	26	29	33	37	41	44	48	52
2½	17	21	26	30	34	39	43	47	52	56	60
2¾	23	29	34	40	46	52	58	64	69	75	81
3	30	37	45	52	60	67	75	82	90	97	105
3¼	38	47	57	66	76	85	95	104	114	123	133
3½	47	59	71	83	95	107	119	131	143	155	167
3¾	58	73	88	102	117	132	146	162	176	190	205
4	71	89	107	125	142	160	178	196	213	231	249

For Simply Transmitting Power and Short Counters.

Diam. of Shaft.	Number of Revolutions per Minute.										
	100	125	150	175	200	233	267	300	333	367	400
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
1½	6.7	8.4	10.1	11.8	13.5	15.7	17.9	20.3	22.5	24.8	27
1⅝	8.6	10.7	12.8	15	17.1	20	22.8	25.8	28.6	31.5	34.3
1¾	10.7	13.4	16	18.7	21.5	25	28	32	36	39	43
1⅞	13.2	16.5	19.7	23	26.4	31	35	39	44	48	52
2	16	20	24	28	32	37	42	48	53	58	64
2⅛	19	24	29	33	38	44	51	57	63	70	76
2¼	22	28	34	39	45	52	60	68	75	83	90
2⅜	27	33	40	47	53	62	70	79	88	96	105
2½	31	39	47	54	62	73	83	93	104	114	125
2¾	41	52	62	73	83	97	111	125	139	153	167
3	54	67	81	94	108	126	144	162	180	198	216
3¼	68	86	103	120	137	160	182	205	228	250	273
3½	85	107	128	150	171	200	228	257	285	313	342

J. & L. Shafting, Concluded.

Horse Power of Cold Rolled Iron Shafting.

As Prime Mover or Head Shaft carrying Main Driving Pulley or Gear, well supported by Bearings.

Diam. of Shaft.	Number of Revolutions per Minute.										
	100	125	150	175	200	225	250	275	300	325	350
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
1 1/2	3 4	4 2	5.	5.9	6.7	7.6	8.4	9.3	10.1	10.9	11.8
1 3/4	5.4	6.7	8.	9.4	10.7	12.1	13.4	14.7	16.1	17.4	18.7
2	8.	10.	12	14	16	18	20	22	24	26	28
2 1/4	11.4	14.2	17	20	27	25	28	31	34	37	39
2 1/2	15.6	19	23	27	31	35	39	43	47	51	55
2 3/4	21	26	31	36	41	47	52	57	62	67	73
3	27	34	40	47	54	61	67	74	81	88	94
3 1/4	34	43	51	60	69	77	86	94	103	112	120
3 1/2	43	53	64	75	85	96	107	118	128	139	150
3 3/4	53	66	79	92	105	119	132	145	158	171	185
4	64	80	96	112	128	144	160	176	192	208	224
4 1/2	91	114	136	159	182	205	228	250	273	296	319

As Second Movers or Line Shafting, Bearings 8 Feet Apart.

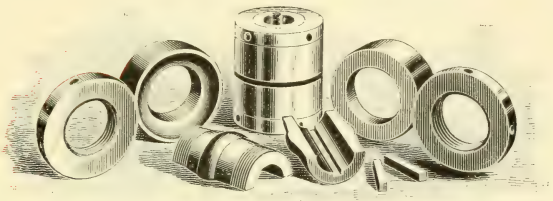
Diam. of Shaft.	Number of Revolutions per Minute.										
	100	125	150	175	200	225	250	275	300	325	350
Inches.	H. P.	H. P.	H. P	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
1 1/8	6 7	8.4	10.1	11.8	13.5	15 2	16.8	18.5	20.2	21.9	23.6
1 5/8	8.6	10.7	12.8	15	17.1	19.3	21.5	23.6	25.7	28.9	31
1 3/4	10 7	13.4	16	18 7	21.5	24.2	26.8	29 5	32.1	34 8	39
1 7/8	13.2	16 5	19.7	23	26.4	29.6	32.9	36.2	39.5	42 8	46
2	16	20	24	28	32	36	40	44	48	52	56
2 1/8	19	24	29	33	38	43	48	52	57	62	67
2 1/4	22	28	34	39	45	50	56	61	68	74	80
2 3/8	27	33	40	47	53	60	67	73	70	86	94
2 1/2	31	39	47	54	62	69	78	86	93	101	109
2 3/4	41	52	62	73	83	93	104	114	125	135	145
3	54	67	81	94	108	121	134	148	162	175	189
3 1/4	68	86	103	120	137	154	172	188	205	222	240
3 1/2	85	107	128	150	171	192	214	235	257	278	300

For simply Transmitting Power and Short Counters.

Diam. of Shaft.	Number of Revolutions per Minute.										
	100	125	150	175	200	233	267	300	333	367	400
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P	H. P.
1 1/4	6.5	8.1	9 7	11.3	13	15.2	17.4	19.5	21.7	23 9	26
1 3/8	8 5	10.7	12.8	15	17	19.8	22 7	25 5	28.4	31	34
1 1/2	11.2	14	16.8	19 6	22 5	26	30	33	37	41	45
1 5/8	14 2	17.7	21.2	24 8	28.4	33	38	42	47	52	57
1 3/4	18	22	27	31	35	41	47	53	59	65	71
1 7/8	22	27	33	38	44	51	58	65	72	79	87
2	26	33	40	46	53	62	71	80	88	97	106
2 1/8	32	40	47	55	63	73	84	95	105	116	127
2 1/4	38	47	57	66	76	89	101	114	127	139	152
2 3/8	44	55	66	77	88	103	118	133	148	163	178
2 1/2	52	65	78	91	104	121	138	155	172	190	207
2 3/4	69	84	99	113	138	161	184	207	231	254	277
3	90	112	135	157	180	210	240	270	300	330	360

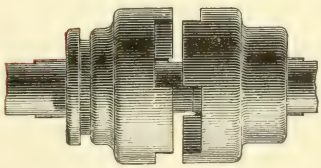
Jones & Laughlin Couplings.

Improved Collins Compression Couplings.

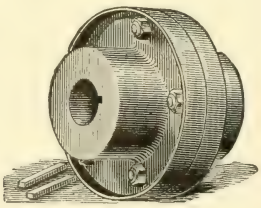


(With Interlocking Keys and Inclined Key-Seats in Coupling and Shafts.)

The sleeve, which is in halves, is bored somewhat smaller than the diameter of the shaft. When the cone rings are driven well home by a copper or babbitt metal hammer or block of hard wood, and locked by the ring nuts on either end, the sleeve is so compressed upon the shaft as to prevent the slightest movement in the connection. As the shafts are not turned down at the ends, the necessity for centering or putting them in a lathe is obviated and the entire strength is preserved.



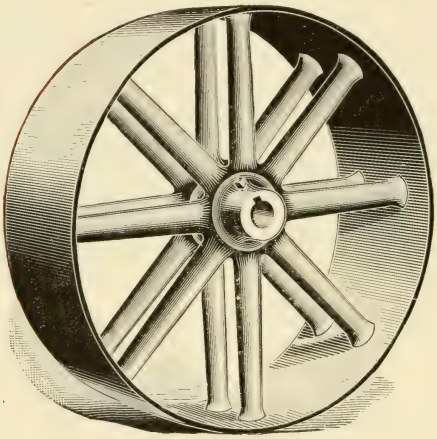
Clutch Couplings.



Flange Couplings.
(Finished All Over, With Tight-Fitting Bolts and Keys.)

Jones & Laughlin Pulleys.

All Kinds of Cast-Iron Pulleys Whatsoever.



Double Arm Pulley.

(Pulleys with faces 20″ wide and over made with two sets of arms.)

More pulleys are broken by undue shrinkage than by all other causes combined. Starting with a suitable mixture of metals, the secret of making a good Cast-Iron Pulley lies in this: It must be properly proportioned in all its parts. Due regard to this law must be observed always, and a disregard of it will always result in failure. A careful observance of it will give Cast-Iron Pulleys that are entirely safe under all reasonable conditions.

Well-made Cast-Iron Pulleys may be employed at, or within, a peripheral speed of a mile a minute. For a higher speed than this we do not advise their use. Within safe speed limits they are preferable to any other kind of pulleys.

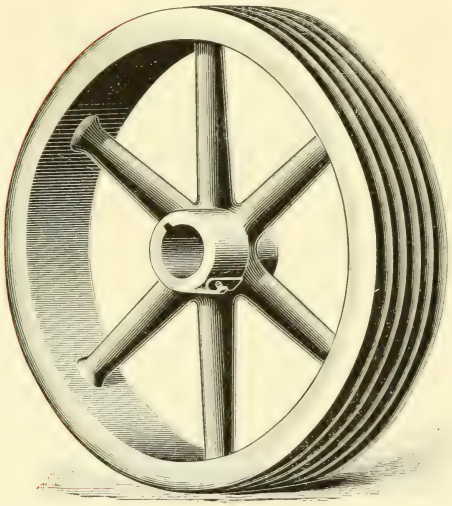
Note.—When ordering pulleys specify whether they are to have Crowning or Straight Face, and whether they are for Single or Double Belt.

Also, state whether to be Key-seated or not.

J. & L. Pulleys, Continued.

Sheaves or Grooved Pulleys.

(For Manila or Hemp Ropes.)



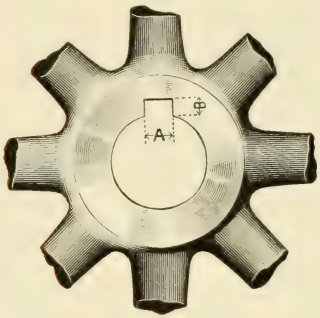
Sheave from 3 feet to 30 feet Pitch Diameter made with any number of Grooves required.

The groove put on should be the "**Engineer's Standard Groove.**" Cuts and dimensions of it for different sizes of rope will be found in the chapter on "**Rope Transmission.**"

J. & L. Pulleys, Continued.

Standard Sizes of Key-Seats for Pulleys.

Note:—Taper for Keys=⅛″ to 1 foot.



Size of Bore.				A. Width of Key-Seat.	B. Smallest Height of Key-Seat.
8	7 7/8			2	21/32
7 3/4	7 5/8	7 1/2	7 3/8	1 7/8	19/32
7 1/4	7 1/8	7	6 7/8	1 3/4	9/16
6 3/4	6 5/8	6 1/2	6 3/8	1 5/8	17/32
6 1/4	6 1/8	6	5 7/8	1 1/2	1/2
5 3/4	5 5/8	5 1/2	5 3/8	1 3/8	29/64
5 1/4	5 1/8	5	4 7/8	1 1/4	27/64
4 3/4	4 5/8	4 1/2	4 7/16	1 1/8	7/16
4 3/8	4 1/16	4 1/4	4 1/16	1 1/16	11/32
4 1/8	4 1/16	4	3 15/16	1	11/32
3 7/8	3 13/16	3 3/4	3 11/16	15/16	5/16
3 5/8	3 9/16	3 1/2	3 7/16	7/8	19/64
3 3/8	3 5/16	3 1/4	3 3/16	13/16	17/64
3 1/8	3 1/16	3	2 15/16	3/4	1/4
2 7/8	2 13/16	2 3/4	2 11/16	11/16	15/64
2 5/8	2 9/16	2 1/2	2 7/16	5/8	13/64
2 3/8	2 5/16	2 1/4	2 3/16	9/16	9/32
2 1/8	2 1/16	2	1 15/16	1/2	11/64
1 7/8	1 13/16	1 3/4	1 11/16	7/16	9/64
1 5/8	1 9/16	1 1/2	1 7/16	3/8	1/8
1 3/8	1 5/16	1 1/4	1 3/16	5/16	7/64
1 1/8	1 1/16	1		1/4	5/32

J. & L. Pulleys, Concluded.

Rules:

In calculating the speed and size of pulleys, the following rules may be easily remembered:

$$\frac{\text{Diam. driving pulley} \times \text{rev. per min.}}{\text{Diam. receiving pulley}} = \textbf{Rev. per min. rec. pulley.}$$

$$\frac{\text{Diam. driving pulley} \times \text{rev. per min.}}{\text{Rev. per min. receiving pulley}} = \textbf{Diam. receiving pulley.}$$

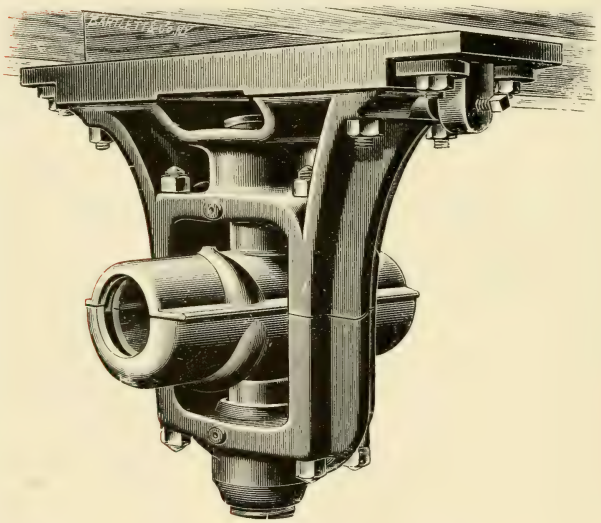
$$\frac{\text{Diam. receiv'g pul.} \times \text{rev. per min.}}{\text{Diameter driving pulley}} = \textbf{Rev. per min. dri. pulley.}$$

$$\frac{\text{Diam. rec. pul.} \times \text{rev. per minute}}{\text{Rev. per min. driving pulley}} = \textbf{Diameter driving pulley.}$$

Jones & Laughlin Hangers.

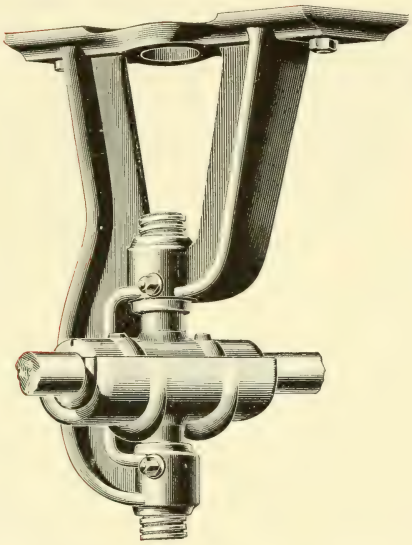
Ring-Oiling Ball and Socket Head Shaft Hangers.

(With Vertical and Horizontal Adjustment.)



Notice:—Various competitors have copied the general design our Hangers. In doing so, however, they have introduced a cheapening system. The balls upon our boxes, the sockets in our plungers, the threads upon the plungers, and in our hanger brackets, all are finished by turning and chasing, and thus securing accurate fits. These parties do none of this fitting, but trust to the accuracy of their castings. Metal cannot be poured always at the same temperature, and the consequence is that the shrinkage in one case will be greater than in others, making a loose and inaccurate bearing and fitting. Our bearings are lined with genuine babbitt metal.

J. & L. Hangers, Continued.



Ring-Oiling Adjustable Ball and Socket Line Hangers.

Length of Bearings=5 diameters of Shaft.
Also length of Bearings=4 diameters of Shaft for 2⅜″ and larger.

Ring Oiling Ball and Socket Post Hangers.

Length of Bearings=5 diameters of Shaft.
Also length of Bearing=4 diameters of Shaft for 2⅜″ and and larger.

Ring-Oiling Wall Bracket Hanger.

(With Vertical and Horizontal Adjustment.)

Length of Bearings=5 diameters of Shaft.

J. & L. Hangers, Continued.

Ring-Oiling Ball and Socket Pillow Blocks.

Length of Bearings=5 diameters of Shaft.
Also length of Bearings=4 diameters of Shaft for 2⅜″ and larger.

Ring-Oiling Rigid Pillow Block.

Length of Bearings=3½ diameters of Shaft.

Rigid Pillow Block.

Length of Bearings=3 diameters of Shaft.

Stands for Ball and Socket Pillow Blocks.

For shafting, on floors or piers, running at high speed and carrying several large pulleys, as in electric light and power stations, our Ball and Socket Ring-Oiling Pillow Blocks on these stands are recommended.

They are **strong** and **rigid**, and insure that the lines shall run with perfect steadiness and truth under the heaviest and most variable loads.

Ring-Oiling Ball and Socket Heavy Floor Stands.

(Adjustable in Every Direction.)

Length of Bearings=5 diameters of Shaft.
Also length of Bearings=4 diameters of Shaft for Shafts 2⅜″ and larger.

This Floor Stand is designed for supporting **safely** and **securely** heavy head shaft carrying main driving pulleys transmitting the duty of double and triple belts. It is strong, heavy and well proportioned.

It is undoubtedly the best Floor Stand made.

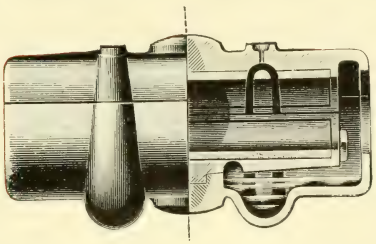
Frequently employed as **Pillow Block** when great flexibility is necessary.

Ring-Oiling Ball and Socket Floor Stands.

(Light Pattern.)

Length of Bearings=5 diameters of Shaft.
Also length of Bearings=4 diameters of Shaft for 2⅜″ and larger.

J. & L. Hangers, Continued.



Ring-Oiling Bearing.

We illustrate above our system of lubricating shafting by tempered steel rings. These rings are bent to circles enough larger than the diameter of their shafts to allow the lower portion of them to run constantly in oil. As the shafts revolve the rings revolve on them and carry up to the journals sufficient oil to lubricate them thoroughly. Any surplus of oil is removed by brass scrapers or wipers at each end of the bearings, and drops back into the oil receptacle.

To remove the oil from the oil receptacle, or cellar, take off the cap of the bearing and pump the oil out with an ordinary rubber bulb syringe.

The bottom half of our bearings is made in two parts, so that should there, by any accident, any dirt get into it, the bearings can easily be taken part and the dirt removed.

Directions for Using Our Ring-Oiling Bearings.

On all hangers 2″ and larger, the brass springs should be so adjusted that when the shaft is placed in position it will depress the scrapers about ¼″. This will allow them to wear that amount before it is necessary to readjust them. A greater depression would cause increased friction and consequent wear. On sizes less than 2″, we have found ⅛″ to $\frac{3}{16}$″ to be about right.

The oiling rings should be put in carefully and the two

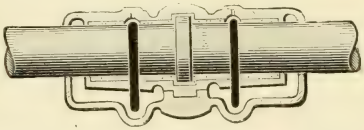
J. & L. Hangers, Continued.

ends brought nicely together, so that they will not catch in turning on the shaft.

We recommend, as the proper amount of oil for the various sizes, as follows:

1½″	Hanger,	¼	pint oil.	3½″	Hanger,	1½	pint oil.
1¾	"	¼	"	3¾	"	1½	"
2	"	½	"	4	"	1	quart oil.
2¼	"	½	"	4¼	"	1½	"
2½	"	½	"	4½	"	1½	"
2¾	"	¾	"	5	"	2	"
3	"	1	"	5½	"	2½	"
3¼	"	1½	"	6	"	3	"

After starting the shafting, the bearings should be carefully watched for a few days, and if any of them become warm the upper half of the bearing should be removed to ascertain the cause of the heat. Being properly started, they should run without trouble for at least a year.



Concealed Collar and Recessed Bearing.

(For Head Shaft of Lines of Shafting.)

Bearings with Ends Closed.

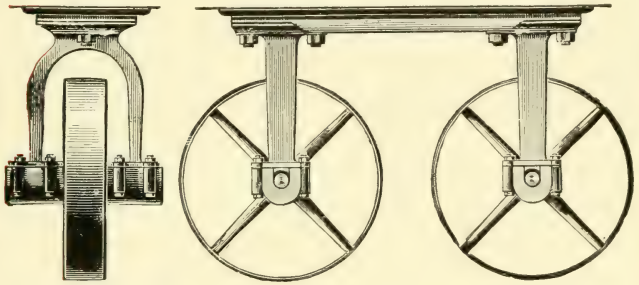
(For Counter Shafts.)

In cotton and other mills where cleanliness is indispensable, collars or shafts outside of the bearings are objectionable because of the liability to throw oil. To avoid this we have adopted the system illustrated above.

Note:—With our ring-oiling bearings no outside collars should be used. Price of concealed collar, or for closing the ends of a pair of bearings, same as the price of a pair of collars.

J. & L. Hangers, Concluded.

Mule pulley stands, binder frames, guide pulleys, etc., are to be avoided if possible. The only exception to this rule is in the case of Jones & Laughlin's special double guides for driving two spinning frames standing across the mill, or at right angles to the shafting. These are equipped with self-oiling bearings and make a very satisfactory spinning drive.



Double Guide.

(For Driving Two Spinning Frames.)

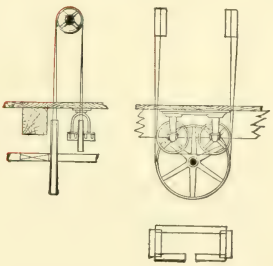


Diagram showing track of belt when frames are driven from below.

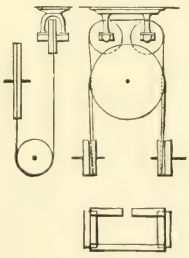
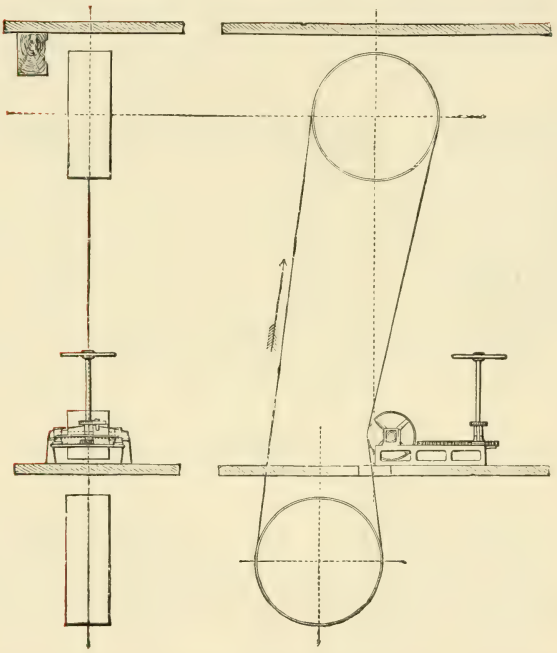


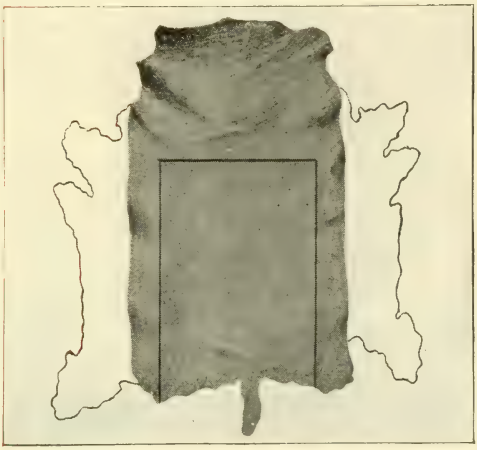
Diagram showing track of belt when frames are driven from above.

J. & L. Belt Tighteners.



This illustrates but one of many styles of belt tighteners. They are to be avoided as a general rule by having larger bolts, by not trying to drive pulleys too nearly over each other, etc.

*SHORT LAP LEATHER BELTING.



This is a strictly short lap belt made from choice cuts only, and is pure oak bark tanned.

In referring to the above diagrams it should be noted that the only portion of the hide used is represented within the heavy lines.

The belting is strictly "short lap"; but as this term is so often misunderstood and equally as often misrepresented, it is not out of place to mention that this term is properly applied to stock cut from the firm solid portion of the hide without running into the shoulder. Length of pieces does not always determine the quality. A large heavy hide affords longer pieces of even a better quality than a smaller and lighter hide. While the average length of our cuts is 4′-2″, some of the very best ones are longer.

Attention is also called to the fact that the weight of the

*See page 350 for "**Specifications for Leather Belting.**"

Short Lap Leather Belting, Continued.

belting so often specified as 16 ounces to the square foot for single belting, is not always an indication of a first class article. Some of the best belting outfits ever put into a cotton mill have averaged little more than 15 ounces to the square foot. For the narrow widths of belting the lighter grades are generally better adapted to give the best service than the heavier ones; as a general rule, the wider belts should be made from the heavier stock, because weight as well as strength is a desirable feature for such belts, which are usually relatively longer.

By referring again to the diagram would state that when stock is cut into the shoulder for long lap belting, the manufacturers necessarily to make uniform belt must use a long lap on the shoulder end which being soft and spongy is a weakness that will determine the life of the belt. Such belting should not be purchased for cotton mill purposes.

For the Southern trade in special cases it is desirable to dress the belting to obviate the effects of the moisture.

Suggestions:

Where narrow belts are to be run over small pulleys, 15′ between centers is a good average. For larger belts running on larger pulleys a distance of 20′ to 25′ is about right. For main driving belts the distance the pulleys should be apart ought not to be less than 25′ to 30′.

With the above distances the slack side while in motion should have a sag of 1½″ to 2″ on the short distances; 2″ to 4″ on the larger belts; and the main belts should have at least 4″ to 5″.

If too great a distance is attempted, the weight of the belt will produce a very heavy sag, drawing so hard on the shafting as to produce great friction in the bearings; while at the same time the belt will have an unsteady flappy motion that tends to wear both the belt and the machinery.

Run the grain or hair side of single belting to the pulleys, because the smooth side will give greater power on account of its better adhesion to the pulleys.

If the belt is made endless at the factory, when it is shipped to the mill it should not be run on to the pulleys, but the shaft should be left out and the belt placed on the pulleys, and the shaft then returned and forced into its place.

Leather belting can not stand a temperature above 110 or 115 degrees without its elasticity being impaired.

Short Lap Leather Belting, Continued.

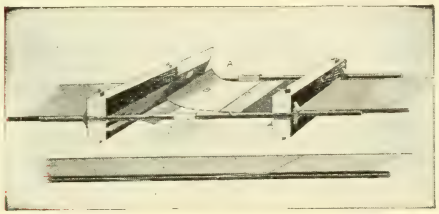
The life of the belting is just about doubled by running it at three fourths, and trebled by running it at one-half its full load.

Belting when subject to sudden strain such as being frequently stopped or started, or shifting belts, should be wider than under ordinary conditions.

The motion in driving should run with and not against the laps of the belts.

It should not be lost sight of that tight belts mean increased friction of the shaft.

Making Belts Endless.



Endless belts not only run more smoothly than laced belts but run longer because of the more even strain where they are fastened together.

It is recommended that all double belts be placed endless on the pulleys, and that each cotton mill provide itself with the following tools for doing that work :

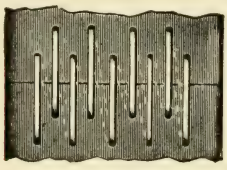
2 belt clamps, one medium and one wide.
1 belt plane.
1 belt scraper.
1 scraper steel.
1 glue brush.
1 glue pot.

In shortening or taking up the slack of an endless belt, adjust clamps to the belt, part splice where originally joined, draw belt to the proper tension, make new splices and recement.

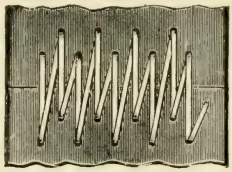
Short Lap Leather Belting, Continued.

Lacing Belts.

Where belts are not made endless but are to be laced, it is extremely important that it shall be carefully done. Punch the holes exactly opposite each other in the two ends, and use only the best lacings. The following cuts will show different methods of lacing.



PULLEY SIDE



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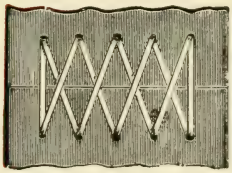

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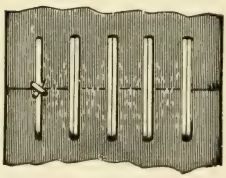

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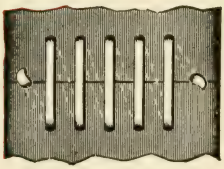

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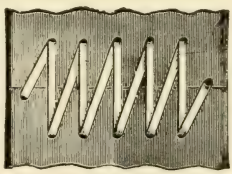

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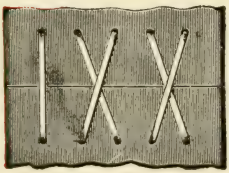

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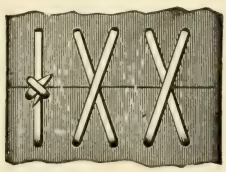
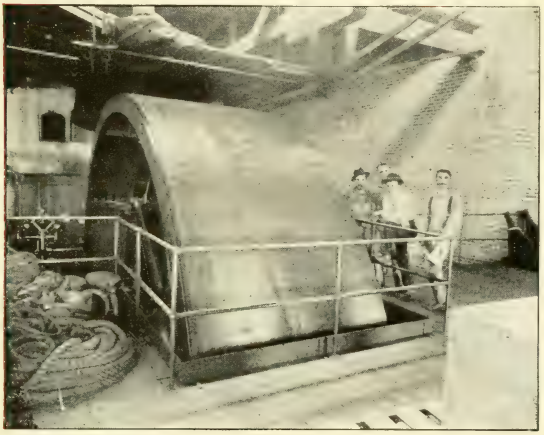


OUTSIDE

No. 4

Short Lap Leather Belting, Continued.



This 84-inch Belt has proven its value. It has now been running several years, and is faultless.

Belt Cement should be used in making belts endless. This cement is to be heated and thinned to the consistency of ordinary glue and applied hot to the surface of the leather, which should be first carefully scraped to insure the removal of old cement. Where repairing is being done, apply pressure if possible ; for new work simply hammering or rubbing down will answer.

Good belting requires nothing except occasionally that it shall be carefully cleaned, dampened slightly, and an application made of **Belt Dressing** to keep it soft and pliable. It also preserves the leather and makes it practically water proof.

Short Lap Leather Belting, Continued.

Measuring Belting in the Roll.

To find the length of belting when closely rolled: The sum of the diameter of the roll and the eye in inches, multiplied by the number of turns in the coil, and this product multiplied by the decimal .131, will equal the length of the belt in feet.

Rules for Calculating Length of Belting.

The following rules will be found useful in calculating the length of belting required when only the distances between centers and the diameter of each pulley can be obtained:

For Open Belts.—Add together the circumference of the two pulleys, and divide the result by two. To this add twice the distance between centers

Where one pulley is much larger than the other, a little extra allowance should be made.

For Cross Belts.—First find the length for Open Belts.

Square each the diameter of the large pulley and the distance between centers; add them together and extract the square root of their sum; subtract from this the distance between centers; multiply the remainder by two.

Add this to the length of the Open Belt previously found, and the result will be the length of the Cross Belt.

Short Lap Leather Belting, Continued.

Transmission of Power by Leather Belting.

It is best to underload rather than to overload belts. The working strain of a belt should never exceed 8% of its breaking strength, which is from 600 to 900 pounds per inch in width for single belts, depending upon the grade.

From the above the theoretical horse power any belt is capable of transmitting, would be figured by multiplying the working strain of a belt per inch in width by the width of the belt in inches, and multiplying this product by the speed of the belt in feet per minute, divided by 33,000; but the actual power transmitted depends upon the amount of slip, which in turn depends upon the arc of contact of the belt with the pulley, which is figured at 180 degrees. This condition is seldom fulfilled in actual practice, and corresponding allowances must be made.

Width of Belt. Inches.	Horse Power per 1,000 feet Belt Speed per Minute. Single Belt.	Double Belt.	Width of Belt. Inches.	Horse Power per 1,000 feet Belt Speed per Minute. Double Belt.
1	1.6		22	55
2	3.3		24	60
3	5.0		26	65
4	6.6	10.0	28	70
5	8 3	12.5	30	75
6	10.0	15.0	32	80
7	11.6	17.5	34	85
8	13.3	20.0	36	90
9	15.0	22.5	38	95
10	16.6	25.0	40	100
12	20.0	30.0	42	105
14	23.3	35.0	44	110
16	26.6	40.0	46	115
18	30.0	45.0	48	120
20	33.3	50.0	50	125

Belts wider than 50 inches can generally be made 3-ply to advantage.

Short Lap Leather Belting, Continued.

Hardly any two engineers or purchasers agree on what should constitute a set of specifications for the best grade of short lap belting. In some cases this is due to a desire to favor a particular maker of belting who affects a certain specification but generally it is due to lack of reliable information on the subject.

Therefore it seems very desirable for the cotton mill trade to have available a set of specifications that shall on the one hand be perfectly free from taint of bias or prejudice; and on the other hand that shall represent a very complete and exhaustive study of the subject by competent authority. I therefore am very glad, indeed, to be able to present the Government Specifications, to which all goods purchased by the Navy Department are required to conform:

Specifications for Leather Belting.

1. The Belting will be short lap. The leather will be tanned by the natural slow process, with pure white-oak bark, unaided by chemicals or bark extracts of any kind: and the leather shall be thoroughly curried.

2. No piece will be more than fifty-four (54) inches long, including laps. Will be cut lengthwise from the extreme end of butt so as to exclude the shoulder, and will be cut entirely from the center or back; no shoulder or belly pieces will be tolerated.

3. Belting will be water-proofed, if so specified, by an approved method; method will be chemically neutral in character, containing neither tallow nor oil.

4. The weights will be as follows, for tan belting not water-proofed; no loading of any description will be tolerated:

Single Belts.

Width.	Weight per square foot.
1″ to 2″	13 ounces
2¼″ to 4″	14 ounces
4½″ to 5½″	15 ounces
6″ and over	16 ounces

Double Belts.

Width.	Weight per square foot
1″ to 2″	26 ounces
2¼″ to 4″	28 ounces
4½″ to 5½″	30 ounces
6″ and over	32 ounces

Short Lap Leather Belting, Concluded.

Specifications for Leather Belting, Concluded.

5. Laps. Single Belts. Belts six (6) inches wide or less, no laps to exceed six (6) inches in length, or to be less than three and one-half (3½) inches in length: single belts wider than six (6) inches, no laps will be more than one (1) inch longer than the belt is wide.

Double Belts. No lap to exceed five and one-half (5½) inches, nor be less than three and one-half (3½) inches in length.

6. Cement. All laps to hold securely at every part, and when pulled apart the surface then exposed shall show no resinous, vitreous, oily or watery condition. No filling straps of any kind will be tolerated.

7. Tests.

(a) Three (3) strips cut lengthwise from any part of the same belt the inspectors may choose, two (2) inches wide, and eight (8) inches long and two (2) inches between centers, and about 0.14 square inches in section at narrowest part must stand an average ultimate tensile stress of at least thirty-six hundred (3600) pounds per square inch of original area of test piece for all single belts and four thousand (4000) pounds for all double belts.

(b) Note:—Under the strong magnifying glass, the direction in which the leather has been cut, can be determined by the direction of the follicles or hair pits, and if, under this inspection, the direction of the follicles is not clearly in a longitudinal direction, this defect will be cause for rejection of the length of belting containing this defect.

Commercial sizes of leather belting, that is, such sizes as would be found in the stock of any manufacturer, range from one inch upward, increasing by quarter inches as far as four inches and by half inches as far as seven inches; above this, the increase is by inches.

Where belting is required for a special purpose, it would conduce towards obtaining the most suitable articles to inform the manufacturer of the nature of the work the belt is for, as well as the average horse power that may be used to drive it, and the speed of the belt in feet per minute.

*ROPE TRANSMISSION OF POWER.

It is only within the last few years that the use of ropes as a means of transmitting power has received the recognition it deserves from mill engineers.

The following are some of the advantages in favor of adopting ropes for the main drive in textile mills:

1. **The Distance and Direction in which Power may be Transmitted is Practically Unlimited.** Satisfactory driving may be done where the distance between shafts is as great as 175 feet, without the aid of carrying pulleys, while with such carriers the distance may be prolonged almost indefinitely. On the other hand, successful driving can be done with ropes where the shafts are close together. There are now in operation many drives whose sheaves are but 10 feet, or even less, centre to centre.

2. **The Amount of Power which may be Transmitted is also Practically Unlimited.** There are several drives, in this country, which are transmitting from 3,000 to 4,000 H. P. with perfect satisfaction.

3 **Economy in First Cost and Maintenance.** In drives of 200 H. P. and up, and where the shafts are more than 30 feet centre to centre, the cost as compared with belts will vary from 15 to 50 per cent. in favor of ropes, according to the distance and size of drive. This advantage increases rapidly as the distance apart of shafts and amount of power transmitted increases.

The small cost of maintenance of a rope drive is a strong point in its favor. The average life of rope on a properly designed drive is from eight to ten years, and during this time the only care it requires is correct splicing, and a "run" free from obstructions.

*Note.—We are indebted to the **American Manufacturing Co.** for permission to borrow from their "**Blue Book on Rope Transmission**," such data as we desire in making up this chapter.

Rope Transmission, Continued.

4. **Economy of Space.** The width of rim surface required in rope drives is only from one-half to two-thirds that required for belting, varying with the size of rope used. It follows, therefore, that the supporting bearings may be placed nearer together for a rope than for a belt drive, an advantage that the practical mill man will recognize as of first importance.

5. **Positive and Steady Running.** The elasticity of the rope, its light weight, and slackness between pulleys take up inequalities in power and load, thereby producing positive and regular running.

6. **Rope Drives are Noiseless**—a fact due to the flexibility and lubrication of the rope, and to the air passage in the groove, between it and the sheaves.

7. **No Electrical Disturbance is Produced.** This is an advantage in textile mills, where such disturbances, caused by belts, are frequently a source of annoyance.

8. **No Loss by Slipping.** In properly designed rope drives, where diameters of the pulleys are sufficiently large and angle of groove correctly turned, loss of power by slipping becomes so infinitesimal that no allowance should be made when calculating speed for driven shaft.

9. **Precise Alignment of Shafting Not Necessary.** When shafts are at an angle with each other, in the same or a different plane, by properly placed guide pulleys power may be transmitted by ropes to great advantage. And where shafting supposed to be parallel has, for one reason or another, been placed at an angle, unless the imperfection is too pronounced the rope will follow the grooves of the sheave, even without the use of an idler.

10. **Transmitting Power to Different Floors.** Where power is to be carried to several floors of a mill, rope driving again stands forth prominently. The full number of ropes start from the driving pulley, while the number required for each different shaft are easily dropped off at the several floors.

11. **Future Additions to Power.** It has become in this country almost an universal custom, in the erection of new mills, to provide for increase of plant. In rope-driving this provision is readily made by installing sheaves with extra grooves, and adding new ropes when additional power is required.

Rope Transmission, Continued.

Two Systems of Rope Driving.

There are two distinct systems of rope-driving, the Multiple, or, as it is popularly known, English system, and the Continuous, or American system.

The Multiple System is the simpler, consisting of one or more independent ropes, running side by side in the grooves of the pulleys. This system is especially adapted to the transmission of large powers, and gives the very best results for drives protected from the weather, where the shafts are parallel or very nearly so, and where the drive is sufficiently off the vertical to prevent ropes, when slack, from leaving the grooves of the lower sheave. With this system, the drive has the utmost security against breakdowns, because of the extreme unlikelihood of more than one rope giving way at the same time. When a failure does occur, the individual rope may be removed and repaired at some convenient time, the delay from such failure being slight, if any. Further, power may be more easily carried to the different floors of a mill; the amount of power transmitted may be more readily increased by the addition of new ropes; the rope always bending in the same direction has a longer lease of life than in the Continuous System, where conditions usually require reverse bending; and finally, it is cheaper to install and maintain.

In the **Continuous System** one rope is wound around the driving and driven pulleys several times. With this system it is necessary by some device to conduct the rope from an outside groove of the delivering, to the opposite outside groove of the receiving pulley, this transfer being accomplished by means of a traveling tension carriage, whose office is to produce a uniform tension throughout the rope, and is so arranged as to travel back and forth, automatically regulating the slack which may occur from stretch in rope, inequalities of load, etc.

The claim occasionally made that ropes of the same diameter will exert more horse power with the Continuous than with the Multiple System, is false. This erroneous idea has

Rope Transmission, Continued.

probably arisen from the fact that makers of the Continuous System, as a general rule, require their ropes to do more work than is the custom with designers of the Multiple System. As a rope will do just so much work in a given time, the practice of increasing the horse power by adding to the tension weight is a bad one, for while it increases the adhesive power, the extra strain put upon the rope necessarily shortens its life. There is no definite rule which can govern the amount of tension weight necessary, as it varies with length of rope, diameter of sheaves, amount of work, etc., but to secure best results and longest life of rope this weight should be just sufficient to give absolute security against any tendency on the part of the rope to slip.

Rope.

In general, ropes for transmission purposes are manufactured from three materials, steel or iron wire, cotton and Manila fibre.

Wire Rope is well adapted for the transmission of large powers to great distances, as for instance in cable and inclined railways. Its rigidness, great weight, and rapid destruction due to bending, however, unfit it for use in mill service, where the average speed of ropes is about 4,000 feet per minute.

Cotton Ropes are advantageously used as bands or cords on the smaller machine appliances: the fibre, being softer and more flexible than Manila hemp, gives better results for small sheaves; but for large drives, where power transmitted is in considerable amounts, cotton rope, as compared with Manila, is hardly to be considered, on account of the following disadvantages: It is less durable; it is injuriously affected by the weather, so that for exposed drives, paper-mill work, or use in water-wheel pits, it is absolutely unsatisfactory; it is difficult, if not impossible, to splice uniformly; even the best quality cotton rope is much inferior to Manila in strength, and for the transmission of equal powers, the cost of a cotton rope varies from one-third to one-half more than Manila.

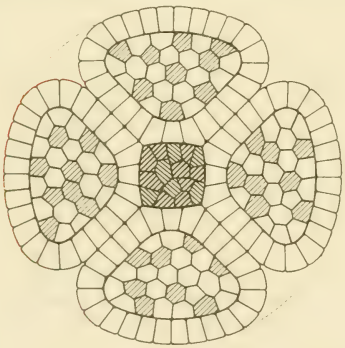
Rope Transmission, Continued.

Manila Transmission Rope is made from the fibre of the *abaca* plant, which grows only in the Philippine Islands. This fibre varies in length from six to twelve feet, and in some leaves attains a length of eighteen feet.

Transmission Rope is made with three, four, or six strands, the four and six strand ropes having an inner core or heart, around which the outer strands are laid.

For small drives, where the diameter of rope is less than ⅞ inch, or where the rope is subject to much bending, the three-strand rope gives excellent results, lending itself readily to abrupt turns.

For the large drives, the four and six strands are preferred; being more nearly circular, and of greater cross section, they secure a larger surface of contact in the groove.



1¾ "American" Transmission Rope Showing Lubricated and Cover Yarns

As before stated, transmission ropes wear out first on the inside, for, in bending about the sheaves, not only is frictional wear caused by the fibres rubbing one against the other, but the yarns which make up the strand slide upon each other and the strands in turn slide upon the core. To overcome this, it is necessary to do more than merely provide large pulleys; the rope must be thoroughly and properly lubricated. The old style transmission rope was laid up with tallow, but tallow not only contains the injurious steric acid, but as a lubricant soon dries out, leaving the inner fibre hard and brittle, and old ropes which externally appeared in good condition, when opened often disclosed the core and adjacent yarns reduced to a fine powder. To overcome this drying effect of tallow upon the ropes, numerous so-called rope-

Rope Transmission, Continued.

dressings were put upon the market. The American Manufacturing Company, going deeper into the matter, hit upon a scientific method of preserving their ropes by treating several of the inner yarns of each strand, as well as the core, in a bath of lubricant, the chief ingredients of which are graphite and fish oil. When the rope is put in service this lubricant thoroughly permeates all the fibres, thus overcoming internal wear, while sufficient comes to the surface to afford ample protection against injurious outside agencies. This lubricant, as we prepare it, never leaves the rope and as long as the strands and yarns remain together they are kept soft and pliable. Ropes so treated are self-lubricating, and need no external dressing whatsoever.

As a further protection against external wear, the outer yarns of each strand are flattened, and arranged on edge around the inner yarns, like keystones of an arch, thus forming a thick covering for each strand.

Suggestions:

Large or Small Ropes. The use of a few large ropes, when consistent with the diameter of the smallest sheave, is the better practice, as the number of splices is lessened, the number of chances of failure decreased, the greater wearing surface of a large rope adds to its life, and, finally, as small ropes are more easily broken than large ones, accidents are more liable to follow their use.

When designing a drive, it would be well first to ascertain, by examining the physical conditions, the largest sheave which may be used advantageously, and then adopt for your drive the largest rope possible, or, in other words, the rope whose diameter does not exceed one-fortieth of the diameter

Rope Transmission, Continued.

of the smallest sheave. For ordinary cases, however, it is not advantageous to use a rope larger than 1¾ inches diameter.

External Rope Dressings. For a drive exposed to the weather a light application of beeswax and tallow will do no harm, but the constant "doping" of protected drives with any of the various dressings now on the market is not only a useless waste of time and money, but in many instances the practice is adverse to best results.

Again, while we believe in an absolutely smooth groove, we do not wish a lubricated one, for the element of slip then becomes too considerable to be ignored by the thoughtful engineer.

American Transmission Rope is self-lubricating, and needs no external dressing whatsoever.

Speed. The most economical speed for a rope has been found from general practice to be from 4,000 to 4,500 feet per minute, for while the amount of work of which a rope is capable increases with the velocity, up to the rate of about 5,200 feet per minute, it is equally true that the wear also increases directly with the speed.

Inclined Multiple Drives. With the shafts 150 feet centre to centre, and but 5° 24′ off the vertical, a drive has been doing satisfactory work for over ten years, during which time but one set of ropes has been in service.

Rolling Motion of Ropes in Groove. It is frequently noticed in Multiple drives that some of the ropes revolve, or roll, in the grooves, while others do not. These non-rolling ropes are soon forced into a wedge shape, and the two sides thus formed sustain the largest proportion of the external wear, while a rope which revolves in the groove will wear

Rope Transmission, Continued.

uniformly. The consensus of opinion among mill men is that the life of a rolling rope is from 15 to 20 per cent longer than that of a wedging rope.

There are several ways of forcing ropes to revolve, the simplest being, where space will permit, to turn the driving sheave slowly, and grasping the rope on tight side near the driven sheave, walk toward the driver, twisting vigorously as you go. A more effective method is to slip the non-rolling rope from its proper groove on the driven sheave and place it in a neighboring groove, running the drive with the rope thus deflected until it begins rolling; upon replacing it in its proper groove the revolving motion will continue.

In short drives, moving the rope one groove out of line will be sufficient, but, where shafts are far apart, a deflection of two, or even three, grooves is usually necessary.

Jumping Ropes. Trouble is sometimes experienced in the Multiple System by ropes jumping from grooves and riding on top of neighboring ropes. This is caused either by bad splicing or sudden variations in load. In the latter case the remedy is to keep ropes spliced fairly tight upon the sheaves and working up to, if not a little beyond, the horse power as given in table. If your splice is correctly made and your ropes are jumping, remove one or more of them from the drive, for ropes do better and steadier work when carrying their full loads.

Rope Splicing.

If the researches of engineers have developed nothing else, they have shown beyond all question that at least ninety-five per cent. of the "troubles" complained of in rope drives are directly caused by bad splicing, notwithstanding that to make a proper transmission splice is a very simple operation, the idea having once been grasped.

Rope Transmission, Continued.

The essential points in a transmission splice are: First, that its diameter be absolutely the same as that of the original rope: second, that it be smooth and free from lumps: third, that the original lay of strands and yarns be disturbed as little as possible; and fourth, that where the several strands are rejoined, each fastening or "tuck" should be made in such manner as to prevent its wearing away and the rope unstranding.

There are many different splices now in use, but after a careful consideration of each we are convinced that all the above features are combined only in what is called the English transmission splice, and experience has proved it the best splice now known.

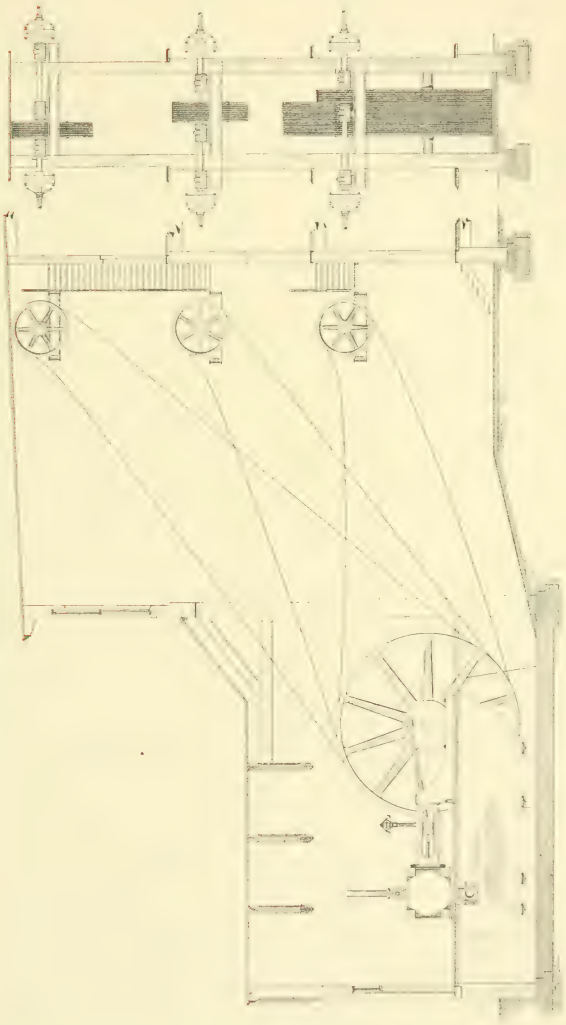
Detailed cuts showing this splicing in different stages while it is being made, with complete descriptions covering the same, had better be obtained from the manufacturers by purchasers and users of rope. The American Mfg. Co. have them for distribution to all of their customers, to insure ropes being properly put on and taken care of.

Re-Splicing Ropes. Do not continually re-splice your ropes in an endeavor to maintain uniform lengths. One rope may appear to be doing more work theoretically than another, owing to its greater surface of contact, but practically all the ropes will be found doing an equal amount of work.

When ropes are to be taken up, do not cut out splice unless it is amply slack to allow for an entirely new one. The English splice when well made can be "backed out" with very little loss of rope. Old ropes when taken up should not be spliced on sheave as taut as when new.

Putting on New Ropes. Before putting a new rope on sheave, keep it in a warm dry place for a day or two. Take out as much stretch as possible with tackle, when measuring on sheaves, but do not stretch the life from the rope by subjecting it to abnormal strain for days before putting it in service.

Rope Transmission, Continued.



Main Drive for Cotton Mill. (Designed by C. R. Makepeace & Co.)
Showing section through Engine Room and Rope Way. Each Jack Shaft is shown with Cut-Off Clutch Couplings on each side in the adjoining rooms.

Rope Transmission, Continued.

Rope Sheaves and Grooves.

In rope drives the pulleys, or sheaves, are second in importance only to the rope itself. The two prominent factors in the construction of the rope sheave are, the relative proportion of its diameter to the diameter of rope used, and the shape and finish of groove.

Transmission ropes wear first internally, the inner yarns becoming disintegrated by the friction caused from constant and rapid bending around sheaves. To limit this disintegration as far as possible, the diameter of the sheave should be made as large as practicable; experience has shown that for economical results a rope should not be made to bend about a sheave whose diameter is less than thirty-six times that of the rope, and, where space and speed of shaft will permit, forty diameters should be used as the minimum. The use of large sheaves not only adds to the life of a rope, but the larger surface of contact gained increases its working power.

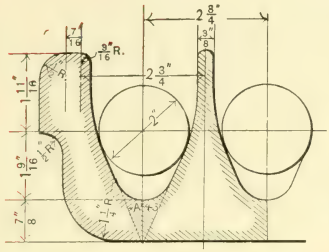
An unlimited variety of grooves have been tried with more or less success All driving and driven sheaves should be turned with a wedge or V-shaped groove of such size and depth that the rope used can never touch the bottom. For idle or carrier pulleys the groove may be U-shaped, however.

So much confusion and annoyance have been caused by the variation in the types of grooves advocated by the manufacturers of sheave pulleys, engine builders, water wheel people, etc., that in order to secure uniformity the leading engineers of the country have finally adopted the

"Engineers' Standard Groove"

of the Jones & Laughlin Steel Co., diagram showing which for the different sizes of rope, is appended on the following page.

"Engineers' Standard Grooves."



Rope Transmission, Continued.

Table 1—Manila Transmission Rope Data.

Diam. of Rope.	Square of Diam.	Approx. Wt. per ft.	Breaking Strength.	Maximum Allowable Tension.	Length of Splice, feet.			Smallest Diam. of Sheaves, inches.	Maximum number of Revolutions per Minute.
					3 Strands.	4 Strands.	6 Strands.		
¾	.5625	.20	3,950	112	6	8	..	27	760
⅞	.7656	.26	5,400	153	6	8	..	32	650
1	1.	.34	7,000	200	7	10	14	36	570
1⅛	1.2656	.43	8,900	253	7	10	16	40	510
1¼	1.5625	.53	10,900	312	7	10	16	45	460
1½	2.25	.77	15,700	450	8	12	18	54	380
1¾	3.0625	1.04	21,400	612	8	12	18	63	330
2	4.	1.36	28,000	800	9	14	20	72	290
2¼	5.0625	1.73	35,400	1,012	9	14	20	81	255
2½	6.25	2.13	43,700	1,250	10	16	22	90	230

Weight of transmission rope..... = .34 × diam.²
Breaking strength..... = 7,000 × diam.²
Maximum allowable tension..... 200 × diam.²
Diam. smallest practicable sheave..... 36 × diam.
Velocity of rope (assumed)..... = 5,400 ft. per min.

Table 2—Horse Power, Manila Rope.

Diameter of Rope.	Velocity, Feet per Minute.										
	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000
¾	2.3	3.3	4.3	5.2	6.0	6.6	7.2	7.3	7.4	7.3	6.9
⅞	3.0	4.5	5.9	7.0	8.2	9.0	9.6	9.8	10.0	9.6	9.0
1	4.0	5.9	7.7	9.2	10.6	11.8	12.7	12.9	13.0	12.7	12.0
1⅛	5.0	7.5	9.7	11.6	13.5	14.9	16.0	16.3	16 7	16.5	15.3
1¼	6.3	9.1	12.0	14.3	16.7	18.5	20.0	20.2	20.7	20.1	18.9
1½	9.0	13.5	17.4	20.7	23.0	26.3	28.7	29.0	29.5	28.6	26.7
1¾	12.3	18.0	23.6	28.2	32.7	36.4	38.5	39.4	40.5	38.7	36.0
2	16.0	23.2	30.6	36.8	42.5	46.7	50.0	51.7	52.8	50.6	47.3
2¼	20.0	29.6	38.6	46.6	53.6	59.2	63.6	65.8	66.3	64.4	60.3
2½	25.0	36.6	47.7	57.5	66.0	71.2	78.0	80.0	81.0	79.0	73.8

While we are aware that many engineers require ropes to do more than is indicated in Table 2, years of experience have shown conclusively that a close approximation to the above powers gives the most economical transmission for general conditions.

Rope Transmission, Concluded.

Table 3—Sag (in feet.)

Distance between Pulleys, Feet.	Sag on Driving Side, All Speeds, Feet.	SAG ON SLACK SIDE. Velocity, feet per Minute.				
		3,000	4,000	4,500	5,000	5,500
30	.19	.45	.39	.36	.33	.30
40	.34	.80	.69	.64	.59	.53
50	.53	1.2	1.1	1.0	.92	.84
60	.76	1.8	1.7	1.4	1 3	1.2
70	1.0	2.4	2.1	1.9	1.7	1.6
80	1.4	3 2	2.9	2.5	2 3	2.1
90	1.7	4.0	3.5	3.2	3.0	2.7
100	2.1	5.0	4.3	4.0	3.7	3.3
120	3.0	7.2	6.2	5.7	5.3	4.8
140	4.1	9.9	8.5	7.8	7.2	6 6
160	5.4	12.9	11.1	10.2	9.5	8.6

The question as to the relative cost of belt and rope driving being frequently asked us, we give below a table of comparison, showing relative costs where the distance apart of shafts varies from 30 to 100 feet, no idlers considered.

Table 4—Relative Cost—Belt and Rope Drives.

Rope Sheaves 18″ diam., 63″ diam. Twelve Grooves.	Belt Pulleys 18″ diam., 63″ diam. 52″ Face.	Shaft Centers, Feet.	Cost of Ropes.	Cost of Belts.	Total Cost Rope Drive.	Total Cost Belt Drive.
$1,226	$1 540	30	$182	$ 646	$1,408	$2,186
"	"	40	217	774	1,443	2,314
"	"	50	252	902	1,478	2,442
"	"	60	287	1,030	1,513	2,570
"	"	70	322	1,158	1,548	2,698
"	"	80	357	1,286	1,583	2,826
"	"	90	392	1,414	1,618	2,954
"	"	100	427	1,542	1,653	3,082

Rim space for ropes = 31 inches ; for belts = 52 inches.

HUMIDIFIERS.

For Moistening the Air in Textile Factories.

Cotton contains about eight per cent. natural moisture, part of which is lost in the process of manufacture unless the proper humidity is maintained in the different rooms. The gain effected by preventing this loss in weight is great enough in itself to justify a nominal cost for an apparatus for that purpose.

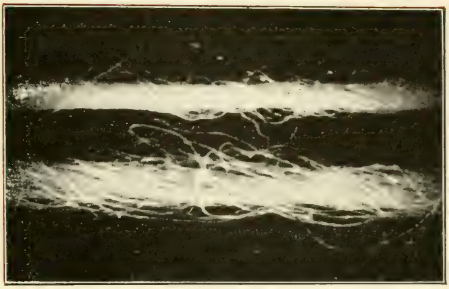
The proper temperature and relative humidity to be maintained in a cotton mill is generally regarded to be about 75° and 75% respectively.

Humidity is essential to lay the electricity ; moist air is a good, and dry air a poor conductor of electricity. A dry and electrically laden atmosphere shortens the threads, weakens the fibre and causes numerous breakages and much more waste is made.

With a certain amount of humidity the fibres become more adhesive and pliant, the yarn is consequently smoother, softer and stronger. The same applies to weaving, breakages become rare, the cloth has a more even and regular structure, any size that is put in the yarn is retained in a softened state.

There are several methods of humidification, but the humidifiers in most common use are jets of water impinging either against themselves or a deflector, thereby producing a fine spray, which is absorbed by the atmosphere. Each apparatus or head disperses 100,000 grains of moisture into the atmosphere per hour, and washes and purifies 20,000 to 30,000 cubic feet of air per hour ; it requires from 50 to 60 gallons of water per hour and works under a pressure of 100 to 120 pounds per square inch. As above indicated, about two gallons of water is actually imparted to the atmosphere and the waste water is returned to the tank and used over again. The amount of humidity is controlled by the regulating valve attached to the apparatus.

NOTE.—See page 956-958, Appendix to this Volume.



Magnifed Views of the Same Number of Cotton Yarns Made Both With and Without Humidifiers—The Upper With and the Lower Without. (Beatty).

So much for the humidification proposition as it strikes the average mill man in this country to-day. It is interesting to note, however, that this subject is one deserving of more thought and investigation than we have been accustomed to give it. As bearing on the general subject and emphasizing the above statement, I herewith quote extracts from "Humidity in Cotton Spinning," by Sir Benjamin Dobson, who is probably the leading authority on this subject throughout the world.

Humidity and Temperature.

"The question of humidity is intimately allied with that of temperature, and in manufactories it is first necessary to fix the temperature at which the work-room shall be kept, and then to make such arrangements that this air may be supplied with the amount of moisture sufficient to make the air soft enough for the comfort of the work-people and the conditioning of the fibre and to render the atmosphere a sufficiently good conductor to subtract the extraneous and superfluous electricity."

"Now, from May 11th, 1896, to January 26th, 1897, a Commission appointed by Parliament sat to take evidence with respect to the working of the Act (Cotton Cloth Factories Act), and this Commission examined a number of witnesses of all classes connected with the industry, and also professional men interested and experienced in the working of the Act. Naturally, the question for investigation would be divided into certain branches, as for instance say, first, the amount of humidity required for successful manufacturing; secondly, the temperature of the work-rooms; thirdly, the comparative purity of the atmosphere in the rooms; fourthly, the means for obtaining the humidity; fifthly, the means of ventilation; sixthly, the method of heating. The report goes on to state that there were various methods of humidification:

(1). Live steam, which means high pressure steam blown into the room from small apertures in pipes.

(2). Humidifiers, which expression includes all kinds of

Humidifiers, Continued.

apparatus and arrangements for forcing into the building air artificially charged with vapor.

(3). By hydraulic spraying (this means finely pulverized water discharged directly into the air).

(4). The ancient and time-honored method of "degging" or watering the floor.

For obvious reasons no attention whatever need be given to the first and fourth of the methods of humidification stated above.

As for the third method termed **hydraulic spraying.** the following extracts are decidedly pertinent:

"We have now to consider the artificial methods of producing moisture. In all systems the water contained in the air in a state of suspension, is either a chemical or mechanical mixture. What I would say is that natural evaporation secures general diffusion and intimate and atomic assimilation; and further, that air and water so assimilated have no tendency to separate by condensation until the conditions of temperature or pressure have necessitated it. On the other hand, in all mechanical appliances for distributing fine particles of water in a proportionate quantity of atmosphere, there is a limit to the power of atomization or pulverization; and, no matter what pressure be used, the sub-division into particles is infinitely inferior in number to the result of natural and free evaporation. Therefore, any system of this kind, whatever its name may be, can only be relatively advantageous as compared with natural systems.

"Now it is found by actual observations that the conditions of moisture in a room naturally humidified is very much more equal than in any mechanical system. This is explained by the facility with which natural vapor can be assimilated by the neighboring air, as opposed to the mechanically powdered water; and may be further illustrated by an example in chemistry, where, in a perfect chemical solution, it is possible to continue dilution until the absorbed substance is one part to a million. In a simply mechanical mixture the limit of dilution is quickly reached. Thus all systems of humidifying which have for the sole principle the pulverization of water, have the initial defect I have alluded to; and they can at best be but a rough and ready way of attempting to solve what is, after all, a simple problem."

"As a still further proof of the inefficiency of this system of humidifying, I point to the fact that it is not practicable to place this apparatus near moving bodies, such as driving straps or shafts; in any case where there is an induced current of air precipitation takes place. To such an extent is this so, that the apparatus has had to be moved from the center of the room to the sides to avoid the action of the shaft and straps upon the air."

"Taking into consideration the cost of the plant, the power, the cost of supervision, the cost of replacement and repairs necessitated where spray humidifiers are employed, and, above all, the inefficiency and inequality of the result as compared with the system of evaporation, I feel justified in declaring that, in my opinion, the cheapest, most efficient, most regular and simplest method of maintaining a constant degree of humidity in an enclosed body of air is the application of some simple system of natural evaporation."

Humidifiers. Continued.

As for the second classification, viz: "**Humidifiers Consisting of Apparatus and Arrangements for Forcing into the Building Air Artificially Charged with Vapor,**" it is obvious that this would be the best system both from a hygienic and a humidification standpoint, if the temperature of the air were also regulated at the same time for heating in winter and cooling in summer. For mechanical and architectural reasons, however, it is impracticable to heat, ventilate and artificially moisten the atmosphere of a room all in one operation to be performed by one system of apparatus.

Still, it is possible to so temper the incoming air as to maintain satisfactory conditions during all but a very short time in the heat of summer and the cold of winter.

In connection with my work both as a mill architect and engineer, and also as a contractor installing machinery in cotton mills, my attention has often been called both by the mill men and by our own erecting men to the annoyance and occasional damage to machinery by the ordinary type of jet humidifier. To this should be added the further facts of the uneven and unequal atmospheric conditions in the different rooms so far as humidity is concerned, which vary not only locally in the different rooms, but also vary greatly from day to day in the same room—all attended with consequent annoyance and difficulty in maintaining the proper draughts and weights in the processes of manufacture. I have therefore given a good deal of thought and study to the subject of providing an apparatus that would be free from these objectionable features.

The principle of an apparatus delivering a jet of water under pressure in such a manner as to break it up into a more or less finely divided condition and then eject the spray into a room, depending upon the atmosphere to pick up and absorb it before it will fall, is clearly wrong. To stand the test of time, such apparatus for this purpose must provide for at least the partial evaporation, absorption and assimilation of the water by the air before it clears the humidifying apparatus itself.

The deductions I have drawn are shared by a number of my friends in the mill business who have likewise given the subject considerable thought and attention, and may be briefly stated as follows:

An ideal system, then, would embrace the best features of the spraying type of humidifiers, and those based upon natural evaporation combined with a provision for both ventilation by the introduction of outside air, and cleansing by the passage through the apparatus of considerable quantities of air from the room itself, and by tempering the incoming

Humidifiers, Continued.

fresh air before it issues from the apparatus by the addition of a moderate amount of heat during the moderate winter months. In summer time the only cooling of the air that is practicable is that due to evaporation; any idea of circulating cold air, artificially cooled, is impracticable. Also the very considerable amount of heat required in the coldest months must likewise be furnished by a regular heating apparatus. The intention of the heat that is applied to the humidifying apparatus should be only to temper the incoming outside air that is brought in for purposes of ventilation. And finally, the spray head itself should deliver the most finely attenuated spray that can be produced—that produced on the principle of atomizing being decidedly preferable to that produced by hydraulic spraying, for the reason that in the former case the tiny globules of water composing the spray are really hollow and extremely minute bubbles instead of minute solid particles of water produced by the latter process, and are consequently more quickly evaporated and assimilated.

But in addition to the above there is another feature yet required to make the system perfect, from the mill man's standpoint, and that is, if possible, it must be automatically controlled and regulated. And, such automatic regulation and control must be capable of taking place intermittently without interfering with the feature of ventilation; in other words, when the humidifying feature is absolutely stopped, ventilation must not be stopped with it but must be continued uniformly throughout the day.

Any system depending upon the attention of the mill operatives, whether overseers or the superintendent himself, is highly objectionable, because those men are busy enough attending to their legitimate functions without being charged with the close watching of the auxiliary apparatus that is necessary to maintain either a uniform temperature or a uniform percentage of humidity.

A New System of Humidification.

It is true there is not on the market at the present time an apparatus embodying all the features above stated, but inside of another year I expect to be in a position to offer such an apparatus to the trade—an apparatus that will not only automatically and positively regulate the humidity, but also the temperature, for I again emphasize the point so well stated by Sir Benjamin Dobson, that "Humidity is intimately allied with that of temperature and it is first necessary to fix the temperature at which the work room shall be kept and to maintain such temperature; and then, to make such arrangements that the air shall be supplied with the necessary amount of moisture, etc."

Humidifiers, Continued.

As stated on page 366, the proper temperature and relative humidity that is ordinarily understood as desirable in a cotton mill is about 75 degrees and 75 per cent. There is a decided advantage, however, in maintaining as high a degree of humidity as the health of the operatives will permit. This question was fully investigated by a commission appointed by Parliament to look into the matter, and embodied in the Cotton Cloth Factories Act, which shows the maximum humidity of the atmosphere permissible at given temperatures, all of which is shown in the following table:

Cotton Cloth Factories Act, 1889.

Maximum limits of humidity of the atmosphere at given temperature.
[Dobson.]

Dry Bulb Readings.	Wet Bulb Readings.	Grains of Moisture per cubic foot of Air.	Percentage of Humidity Saturation =100.	Dry Bulb Readings.	Wet Bulb Readings.	Grains of Moisture per cubic foot of Air.	Percentage of Humidity Saturation =100.
35 deg.	33 deg.	1.9	80	68 deg.	66 deg.	6 6	88
36	34	2.0	82	69	67	6 9	88
37	35	2.1	83	70	68	7 1	88
38	36	2.2	83	71	68.5	7 1	88.5
39	37	2.3	84	72	69	7 1	84
40	38	2.4	84	73	70	7 4	84
41	39	2.5	84	74	70.5	7 4	81.5
42	40	2.6	85	75	71.5	7 65	81.5
43	41	2.7	84	76	72	7 7	79
44	42	2.8	84	77	73	8 0	79
45	43	2.9	85	78	73.5	8 0	77
46	44	3.1	86	79	74.5	8 25	77.5
47	45	3.2	86	80	75.5	8 55	77.5
48	46	3.3	86	81	76	8 6	76
49	47	3 4	86	82	76.5	8 65	74
50	48	3.5	86	83	77.5	8 85	74
51	49	3.6	86	84	78	8 9	72
52	50	3.8	86	85	79	9 2	72
53	51	3.9	86	86	80	9 5	72
54	52	4.1	86	87	80.5	9 55	71
55	53	4.2	87	88	81.5	9 9	71
56	54	4.4	87	89	82.5	10 25	71
57	55	4.5	87	90	83	10 3	69
58	56	4.7	87	91	83.5	10 35	68
59	57	4.9	88	92	84.5	10 7	68
60	58	5.1	88	93	85.5	11 0	68
61	59	5.2	88	94	86	11 1	66
62	60	5.4	88	95	87	11 5	66
63	61	5.6	88	96	88	11 8	66
64	62	5.8	88	97	88.5	11 9	65.5
65	63	6.0	88	98	89	12 0	64
66	64	6.2	88	99	90	12 3	64
67	65	6.4	88	100	91	12.7	64

Hygrometrical Tables.

Giving Both Relative and Actual Humidity at Ordinary Temperatures Shown by the Dry Bulb for Different Depressions of the Wet Bulb.

Temperature.	1°		2°		3°		4°		5°		6°		7°		8°		9°		10°		11°		12°	
	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.
60	94	5.4	88	5.1	82	4.7	76	4.4	71	4.1	66	3.8	62	3.6	58	3.3	54	3.1	50	2.9				
61	94	5.6	88	5.2	82	4.9	77	4.6	72	4.3	67	4.0	62	3.7	58	3.5	54	3.2	50	3.0	47	2.8		
62	94	5.8	88	5.4	82	5.1	77	4.7	72	4.4	67	4.1	62	3.9	58	3.6	54	3.4	50	3.1	47	2.9	44	2.7
63	94	6.0	88	5.6	82	5.2	77	4.9	72	4.6	67	4.3	63	4.0	59	3.7	55	3.5	51	3.3	47	3.0	44	2.8
64	94	6.2	88	5.8	82	5.4	77	5.1	72	4.8	67	4.5	63	4.2	59	3.9	55	3.6	51	3.4	48	3.2	45	3.0
65	94	6.4	88	6.0	83	5.6	78	5.3	73	4.9	68	4.6	63	4.3	59	4.0	55	3.8	51	3.5	48	3.3	45	3.1
66	94	6.6	88	6.2	83	5.8	78	5.5	73	5.1	68	4.8	64	4.5	60	4.2	56	3.9	52	3.7	48	3.4	45	3.2
67	94	6.8	88	6.4	83	6.0	78	5.6	73	5.3	68	5.0	64	4.7	60	4.4	56	4.1	52	3.8	49	3.6	46	3.3
68	94	7.1	88	6.6	83	6.2	78	5.8	73	5.5	68	5.2	64	4.8	60	4.5	56	4.2	52	4.0	49	3.7	46	3.5
69	94	7.3	88	6.9	83	6.5	78	6.1	73	5.7	68	5.3	64	5.0	60	4.7	56	4.4	53	4.1	50	3.9	47	3.6
70	94	7.5	88	7.1	83	6.7	78	6.3	73	5.9	69	5.5	65	5.2	61	4.9	57	4.6	53	4.3	50	4.0	47	3.8
71	94	7.8	88	7.3	83	6.9	78	6.5	73	6.1	69	5.7	65	5.4	61	5.1	57	4.7	53	4.4	50	4.2	47	3.9
72	94	8.0	89	7.6	84	7.1	79	6.7	74	6.3	69	5.9	65	5.6	61	5.3	57	5.0	54	4.7	51	4.4	48	4.1
73	94	8.3	89	7.8	84	7.4	79	7.0	74	6.6	70	6.2	66	5.8	62	5.4	58	5.1	54	4.8	51	4.5	48	4.2
74	94	8.6	89	8.1	84	7.6	79	7.2	74	6.8	70	6.4	66	6.0	62	5.6	58	5.3	55	5.0	52	4.7	48	4.4
75	94	8.9	89	8.4	84	7.9	79	7.4	74	7.0	70	6.6	66	6.2	62	5.8	58	5.5	55	5.2	52	4.9	49	4.6
76	94	9.2	89	8.6	84	8.2	79	7.7	75	7.2	71	6.8	67	6.4	63	6.1	59	5.7	55	5.4	52	5.1	49	4.8
77	94	9.5	89	8.9	84	8.4	79	8.0	75	7.5	71	7.1	67	6.7	63	6.3	59	5.9	56	5.6	53	5.3	50	4.9
78	94	9.7	89	9.2	84	8.7	79	8.2	75	7.8	71	7.3	67	6.9	63	6.5	59	6.2	56	5.8	53	5.5	50	5.1
79	95	10.1	90	9.5	85	9.0	80	8.5	75	8.0	71	7.6	67	7.2	63	6.8	59	6.4	56	6.0	53	5.6	50	5.3
80	95	10.4	90	9.8	85	9.3	80	8.8	75	8.3	71	7.8	67	7.4	63	7.0	59	6.6	56	6.2	53	5.8	50	5.5

Note.—For explanation of tables, see pages 372-5.

Hygrometrical Tables. Continued.

Temperature.	13°		14°		15°		16°		17°		18°		19°		20°		21°		22°		23°		24°		25°	
	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.
60																										
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69																										
70																										
71																										
72	45	3.8																								
73	45	4.0	42	3.7	40	3.5	37	3.3																		
74	45	4.1	43	3.9	40	3.6	37	3.4	35	3.0	33	3.0														
75	46	4.3	43	4.0	40	3.8	38	3.6	36	3.2	33	3.1														
76	46	4.5	43	4.2	40	3.9	38	3.7	36	3.3	34	3.3														
77	47	4.6	44	4.3	41	4.1	38	3.9	36	3.4	34	3.4														
78	47	4.8	44	4.5	41	4.3	39	4.0	37	3.8	35	3.5														
79	47	5.0	44	4.7	41	4.4	39	4.2	37	3.9	35	3.7	32	3.5												
80	47	5.2	44	4.9	41	4.6	39	4.3	37	4.1	35	3.8	33	3.6												

Note.—For explanation of tables, see pages 372–5.

The tables show the relative and actual humidity for air at ordinary temperatures, by noting the difference between readings of the wet and dry bulb thermometers. The wet bulb is cooler and of lower temperature than the dry bulb, and the difference between the readings of the wet and dry bulbs is designated "depression of the wet bulb." The relative humidity expressed as a percentage is catalogued under the heading "R"; the actual humidity in grains of vapor per cubic foot of atmosphere is catalogued under the heading "A."

Example: Dry Bulb, 80 degrees; Wet Bulb, 73 degrees; difference, or depression of the wet bulb, 7 degrees; under 7 degrees difference and opposite 80 degrees, the temperature of the air as shown by the dry bulb, we find 67 degrees relative humidity and 7.4 actual humidity.

Hygrometrical Tables, Continued.

Temperature.	1°		2°		3°		4°		5°		6°		7°		8°		9°		10°		11°		12°	
	R.	A.	R.	A.	R.	A.	R.	A.	R	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.
81	95	10.7	90	10.1	85	9.5	80	9.1	76	8.6	72	8.1	68	7.6	64	7.2	60	6.8	56	6.4	53	6.0	50	5.7
82	95	11.1	90	10.5	85	9.9	80	9.4	76	8.9	72	8.4	68	7.9	64	7.5	60	7.1	57	6.7	54	6.3	51	5.9
83	95	11.7	90	10.8	85	10.2	80	9.7	76	9.1	72	8.6	68	8.2	64	7.7	60	7.3	57	6.9	54	6.5	51	6.1
84	95	11.7	90	11.1	85	10.5	80	10.0	76	9.4	72	8.9	68	8.5	64	8.0	60	7.5	57	7.1	54	6.7	51	6.3
85	95	12.1	90	11.5	85	10.9	80	10.3	76	9.7	72	9.2	68	8.7	64	8.3	61	7.8	58	7.4	55	7.0	52	6.6
86	95	12.5	90	11.8	85	11.2	80	10.6	76	10.1	72	9.5	68	9.0	64	8.5	61	8.1	58	7.6	55	7.2	52	6.8
87	95	12.9	90	12.2	85	11.6	81	11.0	77	10.4	73	9.8	69	9.3	65	8.8	61	8.3	58	7.9	55	7.4	52	7.0
88	95	13.3	90	12.6	85	12.0	81	11.4	77	10.8	73	10.2	69	9.6	65	9.1	61	8.6	58	8.1	55	7.7	52	7.3
89	95	13.7	90	13.0	85	12.3	81	11.7	77	11.1	73	10.5	69	10.0	65	9.4	61	8.9	58	8.4	55	8.0	52	7.5
90	95	14 1	90	13.4	85	12.7	81	12.1	77	11.4	73	10.8	69	10.3	65	9.7	62	9.2	59	8.7	56	8.3	53	7.8
91	95	14.5	90	13.8	86	13.1	82	12.5	78	11.8	74	11.2	70	10.6	66	10.1	62	9.5	59	9.0	56	8.5	53	8.1
92	95	14.9	90	14.2	86	13.5	82	12.8	78	12.2	74	11.6	70	11.0	66	10.4	62	9.9	59	9.3	56	8.8	53	8.3
93	95	15.4	90	14.7	86	14.0	82	13.3	78	12.6	74	11.9	70	11.3	66	10.7	63	10.2	60	9.6	57	9.1	54	8.7
94	95	15.9	90	15.1	86	14.4	82	13.7	78	13.0	74	12.3	70	11.7	66	11.1	63	10.5	60	10.0	57	9.5	54	9.0
95	95	16.3	90	15.5	86	14.8	82	14.1	78	13.4	74	12.7	70	12.1	66	11.5	63	10.9	60	10.3	57	9.8	54	9 3
96	95	16.8	90	16.0	86	15.2	82	14.5	78	13.8	74	13.1	70	12.4	66	11.8	63	11.2	60	10.7	57	10.1	54	9.6
97	95	17.3	90	16.5	86	15.7	82	14.9	78	14.2	74	13.5	70	12.8	67	12.2	64	11.6	60	11.0	57	10.4	54	9.9
98	95	17.8	90	17.0	86	16.2	82	15.4	78	14.6	74	13.9	70	13.2	67	12.6	64	12.0	61	11.4	58	10.8	55	10.2
99	95	18.4	90	17.5	86	16.7	82	15.9	78	15.1	74	14.4	71	13.7	67	13.0	64	12.3	61	11.7	58	11.1	55	10.5
100	95	18.9	90	18.0	86	17.2	82	16.3	78	15.5	74	14.8	71	14.1	68	13.4	64	12.7	61	12.1	58	11.5	55	10.9

Note.—For explanation of tables, see pages 372-5.

Hygrometers.—Humidity is most conveniently and accurately measured by a hygrometer, consisting of two thermometers attached to a support. The bulb of one thermometer has thin muslin tied over it, and is kept moist by the capillary action of yarn dipping into a cistern of water placed underneath. It will be obvious that the amount of evaporation will be in proportion to the dryness of the air, and that the differences of temperature indicated by the two thermometers will be greatest when the atmosphere is dry, and least when the air is damp.

Hygrometer Precautions.—Hygrometers should be placed free from air currents and kept amply supplied with soft water (distilled if possible). Change muslin and wick occasionally if it is noticed the wet bulb is not constantly moist.

Hygrometrical Tables, Concluded.

Temperature.	13°		14°		15°		16°		17°		18°		19°		20°		21°		22°		23°		24°	
	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.	R.	A.
81	47	5.4	44	5.1	41	4.8	39	4.5	37	4.2	35	4.0	33	3.7										
82	48	5.6	45	5.2	42	4.9	40	4.7	38	4.4	35	4.1	33	3.9	31	3.6								
83	48	5.8	45	5.4	42	5.1	40	4.8	38	4.6	36	4.3	34	4.0	32	3.8	30	3.6						
84	48	6.0	45	5.6	43	5.3	40	5.0	38	4.7	36	4.5	34	4.2	32	4.0	30	3.7	28	3.5				
85	49	6.2	46	5.9	43	5.5	40	5.2	38	4.9	36	4.6	34	4.3	32	4.1	30	3.8	28	3.6				
86	49	6.4	46	6.1	43	5.7	40	5.4	38	5.1	36	4.8	34	4.5	32	4.2	30	4.0	28	3.7	27	3.5		
87	49	6.6	46	6.3	43	5.9	41	5.6	39	5.3	37	5.0	35	4.7	33	4.4	31	4.2	29	3.9	27	3.7		
88	49	6.9	46	6.5	43	6.1	41	5.8	39	5.5	37	5.2	35	4.9	33	4.6	31	4.3	29	4.1	27	3.8		
89	49	7.1	46	6.7	43	6.4	41	6.0	39	5.7	37	5.4	35	5.1	33	4.8	31	4.5	29	4.2	28	4.0		
90	50	7.4	47	7.0	44	6.6	42	6.2	40	5.9	38	5.6	36	5.3	34	5.0	32	4.7	30	4.4	28	4.2		
91	50	7.7	47	7.2	44	6.8	42	6.5	40	6.1	38	5.8	36	5.5	34	5.1	32	4.8	30	4.5	28	4.3		
92	50	7.9	47	7.5	45	7.1	43	6.7	41	6.3	38	6.0	36	5.7	34	5.3	32	5.0	30	4.8	28	4.5		
93	51	8.2	48	7.8	45	7.4	43	6.9	41	6.6	38	6.2	36	5.9	34	5.5	32	5.2	30	5.0	29	4.7		
94	51	8.5	48	8.0	45	7.6	43	7.2	41	6.8	39	6.4	37	6.1	35	5.7	33	5.4	31	5.1	29	4.9		
95	51	8.8	48	8.3	45	7.9	43	7.5	41	7.1	39	6.7	37	6.3	35	6.0	33	5.6	31	5.3	30	5.0		
96	52	9.1	49	8.6	46	8.2	43	7.7	41	7.3	39	6.9	37	6.5	35	6.2	33	5.9	31	5.6	30	5.3		
97	52	9.4	49	8.9	46	8.4	44	8.0	42	7.6	39	7.2	37	6.8	35	6.4	33	6.1	31	5.8	30	5.5		
98	52	9.7	49	9.2	46	8.7	44	8.3	42	7.8	40	7.4	38	7.1	36	6.7	34	6.3	32	6.0	30	5.7		
99	52	10.0	49	9.5	46	9.0	44	8.6	42	8.1	40	7.7	38	7.3	36	6.9	34	6.6	32	6.2	30	5.9		
100	52	10.4	49	9.9	47	9.4	45	8.9	43	8.4	40	8.0	38	7.6	36	7.2	34	6.8	32	6.4	30	6.1	29	5.8

Note.—For explanation of tables, see pages 372-5.

Relative and Actual Humidity.—Humidity is stated as either relative or actual. Complete saturation of the air with moisture is stated as 100, and relative saturation by smaller percentages.

Actual humidity is the weight in grains per cubic foot of the vapor in the air.

The dew point is the temperature at which the moisture present in the air completely saturates it and precipitation takes place.

DIRECT STEAM HEATING.

Many cotton mills in the South are heated by **direct radiation from steam pipes** hung from the overhead timbers, the moving belts causing the heated air to circulate and thereby to become equally distributed in the rooms. Both live and exhaust steam are used; in the former case the water of condensation can be returned to the boilers by gravity; in the latter system it has to be returned by an automatic pump and receiver. The use of exhaust steam puts a back pressure on the engine and on this account the system is condemned by many mill men, though with heating pipes amply large and other conditions favorable it can be made to work to advantage where non-condensing engines are used.

Of course, with condensing engines, only a live steam heating system can be used, and that should be through the medium of a reducing valve; this requires an automatic pump and receiver to return the water of condensation to the boilers.

Some mills let the water of condensation go to waste from a trap, but that is throwing money away. It is all right, however, to let it waste from a trap into a hot well where it will go right back into the boilers and thereby dispense with an automatic pump and receiver.

The principal objection to this system is that it provides no ventilation and in winter the air of mills so heated becomes close and foul; therefore suitable provision should be made for ventilation independently of the heating apparatus.

With independent means for ventilating, it is believed that heating can be most satisfactorily and most economically furnished by this system of direct radiation from either steam pipes or hot water pipes, the preference being given to the former.

Notes on Installation.

Main Supply Pipe—The steam supply is usually taken from an opening in main steam drum of power plant left for that purpose, except in water power plants in which case a boiler is installed for steam heating, dye house and other auxiliary purposes. The size of main steam supply is determined from the number of square feet of radiating surface to be supplied.

Rule for computing size of main steam supply: Divide the amount of direct heating surface in square feet by 100; divide the quotient by .7854; then extract the square root of the quotient; the result will be the diameter of the supply pipe in inches.

The reducing valve should be placed on the main supply pipe in engine room or other convenient place for the observation of engineer, and as near to outlet in drum as

Direct Steam Heating, Continued.

possible. It is ordinarily set at 20 lbs. Immediately after reducing valve there should be placed in main steam supply pipe a steam gauge for registering the steam pressure on the heating system.

Circulating Pipes—The custom is to run several rows of pipe around the inside of each room, the size and number of rows depending on the width of the room and the character of work going on. The following schedule gives the usual practice for a live steam system:

For a mill 50 feet wide, three rows of 1" pipe in main mill, two rows in picker room.

For a mill 75 feet wide, same as above but using 1¼" pipe, and two rows in picker room.

For a mill 100 feet wide, four rows of 1¼" pipe in mill, and two rows in picker room.

The above figures are based on the following ratios under ordinary conditions:

For weave room, 1 sq. ft. of radiating surface to 175 cu. ft. in room.

For carding and spinning rooms, 1 sq. ft. of radiating surface to 250 cu. ft.

For picker rooms, 1 sq. ft. of radiating surface to 350 cu. ft.

2.9 lineal feet of 1" pipe, or 2.3 lineal feet of 1¼" pipe, contain one square foot of radiating surface.

The pipes should be very carefully put up, with a gradual fall of ¼" to ⅜" in ten feet, so the water of condensation will flow uninterruptedly back to the trap receiver or boilers, as the case may be. Any low or high places will "trap" the system, and cause it to be noisy. Of course, the pitch should be toward the boilers in the main steam pipes until the reducing valve is passed, and after that from the boilers.

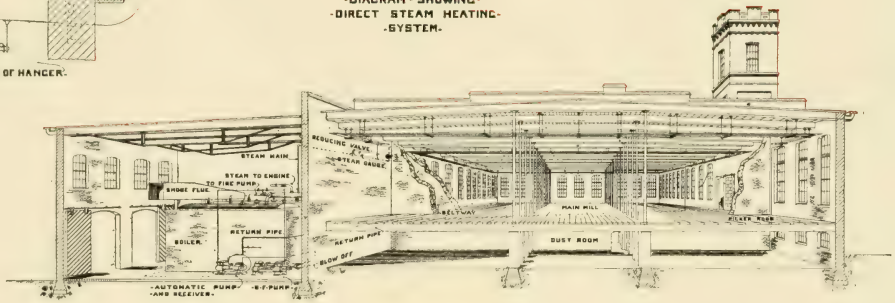
The pipes are to be hung on rollers to permit of free expansion and contraction. These are suspended by hangers from ceiling flanges fixed to the roof beams overhead at the sides of the mill, and to the ceiling or roof planks at the ends of the mill. The flanges should be drilled and tapped, and the hangers cut to length to give the proper grade or pitch to the piping.

Valves—Valves used in the construction of heating system should be straight-way gates, both on feeds and returns.

Automatic Pump and Receiver—The return pipe should be connected up with an automatic pump and receiver which returns the water to the boilers through blow-offs or main feed pipes. Steam for operation of pump is taken from a point where high pressure steam can be obtained.

Direct Steam Heating, Concluded.

-DIAGRAM - SHOWING-
-DIRECT STEAM HEATING-
-SYSTEM-



Testing System.—System should be well blown out with high pressure steam before connecting up with pump and receiver. This precaution prevents scales in pipes from being carried into receiver and thence to pump where they will injure pump valves. The system should test out and operate free from hammering or other noise.

Boiler Horse Power Required.—In close figuring, one boiler horse can be allowed to each 125 feet of radiating surface; but as a general rule this is figured on a ratio of 100 to 1.

The Webster System.—When direct steam heating is employed, it is well to install the Webster System. It is also applicable to slashers, drying cylinders in dye houses, etc. The system is based upon the flow of steam and condensation from a pressure slightly above the atmosphere (say two pounds) into a pressure slightly below,—a partial vacuum. The supply pipes, radiating surfaces, and return pipes are exhausted in advance of the turning on of the steam. After all the supply pipes and radiating surfaces are filled with steam, a thermostatic water and air relief valve prevents the steam from escaping into the return lines by thermostatic action, while permitting the removal of the condensed water and air. A special pump automatically controlled is connected to the main return pipe, to maintain the partial vacuum and to remove the air and condensation from the returns; the condensed water is delivered into a receiver or returned to the boilers, and the air escapes.

HEATING AND VENTILATION

Ducts and Flues.

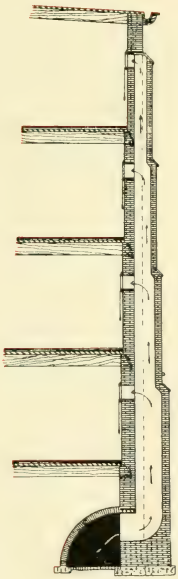


Fig 1.

Heating and ventilating with a forced circulation by means of a fan operated in connection with a heater, has many advocates. It is questionable, however, if it really possesses as many advantages in the South as it does in a colder climate requiring closing up the mill tightly all day in cold weather. Its only real point of merit for the Southern trade is that it does away with overhead steam pipes, and thereby makes a neater job; as for its feature of ventilation, I consider that it can better be handled as an independent feature.

The following description will make clear the installation of an outfit such as is ordinarily installed of this kind:

From the fan outlet a longitudinal flue distributes the hot air from the apparatus to vertical pilaster flues in the wall, each of which has suitable outlets upon each floor, equipped with dampers. Fig. 2 illustrates a typical outfit as applied to a textile mill building. The system is so simple that the cut will make it sufficiently clear without an elaborate explanation. In general, however, it is well to remark that the flues are located from forty to seventy-five feet apart, along the rear wall of the mill, and the openings with dampers placed some ten feet above each floor. As great strength of wall is usually necessary in mill building, the weakening of the wall is avoided by building the flues as pilasters between the windows and entirely outside the building, the exterior walls around the flues being double four and eight inches thick, well bonded, preferably with air spaces between to prevent loss of heat. The amount of air admitted to the various stories is regulated by special dampers of the type shown in the cut. The flues are reduced in area both longitudinally

Heating and Ventilation, Continued.

Fig. 2.

and vertically as the air is discharged to the different floors through the different outlets so as to regulate more equally the supply to each and at the same time to economize material, and, so far as the vertical flues are concerned, to give a better architectural effect. The fan is generally of the three-quarter housing type, arranged to discharge downward into a brick duct connected with the longitudinal flue. This longitudinal flue in its most approved type forms in section what is known as a quadrant arch, as shown in Fig. 1. Connection from the longitudinal flue is made

Heating and Ventilation, Continued.

with each pilaster flue, which, as already noted, gradually decreases as it extends upward to compensate for the air delivered to the various floors. Both the cuts make clear the general construction of the pilaster flues, openings and dampers. Referring specially to the latter, however, it is to be noted that it consists of a cast iron frame bricked into the wall. Pivoted at the top of this frame and swinging inward is a sheet iron plate serving the double purpose of damper and deflector, and adjustable by a worm on the end of the vertical rod acting upon a gear on the damper axis to move it to any desired position. This rod extends down to within easy reach of the operative.

Fans.

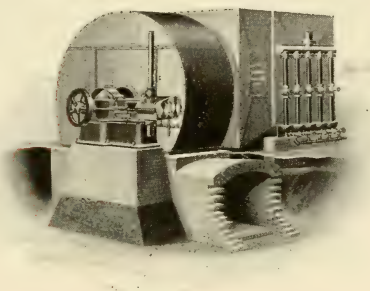
Fan and Heater Apparatus is either Engine Driven or Belt Driven, or provision made for both, as may be desired.

Of course, it is more economical to run the fan from the main engine, especially when that engine is a very economical one of the compound condensing type; at the same time, it is generally desirable to have the heater apparatus in operation half an hour in the morning before the main engine is started. Provision for this can be made by the use of a small auxiliary engine for driving electric lights, machine tools, and the fan and heater apparatus when the main engine is not running; in such an arrangement we usually drive from both the auxiliary and main engine on to a countershaft and then to the belt driven fan. Many customers, however, prefer a separate engine either directly attached or belted to a third pulley on the fan, a typical example of which we show on the duplex apparatus on a subsequent page. These engines are furnished either vertical or horizontal as circumstances may require.

In any case, where an apparatus is driven either by a separate engine direct or by a small auxiliary engine, as above described, provision should be made so that if desired it can be run at night in very severe weather and the exhaust steam from its engine turned into its heater, which would be sufficient to keep the rooms fairly comfortable.

The following illustrations show only a very few of the styles of apparatus and methods of driving the same. Each case should be treated separately and special apparatus constructed to suit its own peculiar requirements.

Heating and Ventilation, Continued.



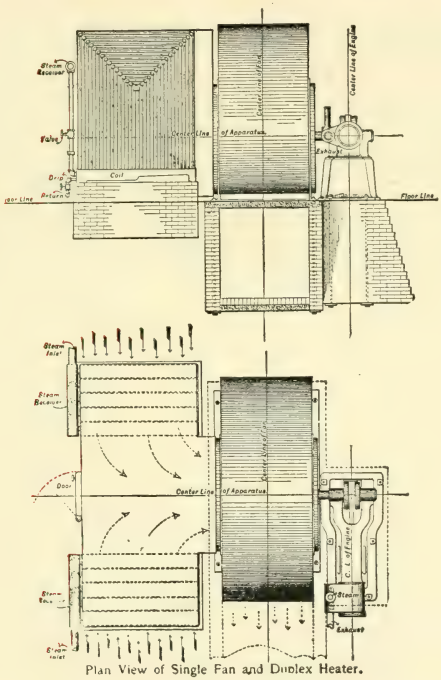
(Three-quarter Housing Fan, Left Hand Bottom Horizontal Discharge, Drawing Through Heater. Direct-Attached Horizontal Engine.)

Heating and ventilating apparatus is known either as **"Draw-through Apparatus"** or **"Blow-through Apparatus."** It is usually located in the basement at some suitable point where steam connections and power can be easily obtained, also preferably where it is easy of access by the engineer. Frequently, however, a special fan house is built adjoining engine room.

Standard Heating and Ventilating Apparatus.

This is generally of the **"Draw-through type,"** the air first passing through the heater before it enters the fan. In its simplest form, the fan is of the steel plate pattern, belt driven, either with overhung pulley or furnished with outboard bearing, according to the size of the outfit; the heater consists of independent sections of one-inch pipe with a properly connected system of valves to render possible the use of any number of these sections at a time. Obviously more or less of these sections can be provided, and they can be separated by a blank flange in such a manner as to permit of using live steam in one of the groups thus formed and exhaust steam in the other. The low pressure steam coils are always so located as to be first presented for contact

Heating and Ventilation, Continued.



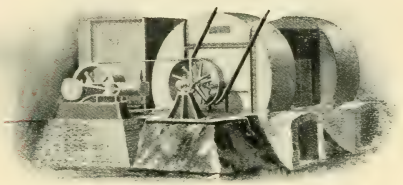
Plan View of Single Fan and Duplex Heater.

Three-quarter Housing Fan, Right Hand, Bottom Horizontal Discharge, Drawing Through Duplex Heater, Direct Attached Horizontal Engine.

(Buffalo.)

with the air before it passes across the pipes of the high pressure group where its temperature is increased. The drip or condensation from the heater is either disposed of by trapping it to the atmosphere or returned to the hot well or the boilers with an automatic pump and receiver. The fans are usually of the three-quarter housing type, with the discharge in any direction desired.

Heating and Ventilation, Continued.



Duplex Heating and Ventilating Apparatus, with Three Pulley Rig.

(Sturtevant.)

The advantages of a duplex fan are obvious in that greater capacity can be secured within a given height, and the danger of inconvenience from accident is less.

Several arrangements of the heater are possible with the duplex fan, the most common being that shown in the above cut. The fans are built as exhausters, each with only a single inlet, and that on the side opposite the engine. These two inlet sides face each other, so that the entire space between the fans and connecting with these inlets can be readily enclosed and connected with the heater, which is usually symmetrically arranged and placed immediately behind the fans. The heater shown in the cut is constructed in three groups, forming three sides of a square, and offering a large area for the admission of air to the fans ; only the open end of one group is clearly represented. The sections being arranged symmetrically, a uniform velocity of the entering air is secured through all parts of the heater.

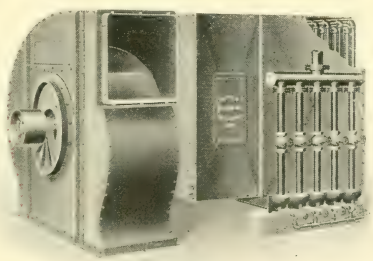
A special arrangement of tight and loose pulleys is introduced, so as to allow of driving the fans by belt from the main line during the day, and by belt from a small independent engine during the night. The engine is of the

Heating and Ventilation, Continued.

regular horizontal type, and is provided with an extra heavy fly wheel, with face of double width, to permit of the shifting of the belt

The middle pulley upon the fan is rigidly keyed to the fan shaft. The other two pulleys, one on either side, are carried upon sleeves extending from the ends of the adjacent boxes. When the fan is to be driven by the engine, the belt from the latter is shifted on to the middle pulley, while that from the line shaft, which is usually standing still during the operation of the fan engine, is left idle upon the pulley nearest the fan.

This type of apparatus is generally placed midway of the length of the mill, and discharges the heated air into a continuous brick duct extending along the wall on one side of the mill. The ducts from the two fans join before entering this main duct, and are provided at their junction with a gate which automatically regulates the discharge of air from the fans, and completely closes the outlet of either fan if it is stopped.



Full Housing Fan, Left Hand, Top Horizontal Discharge, Drawing Through Heater. Pulley for Belt.

(Buffalo.)

Heating and Ventilation, Continued.

Blow-Through Heating and Ventilating Apparatus.

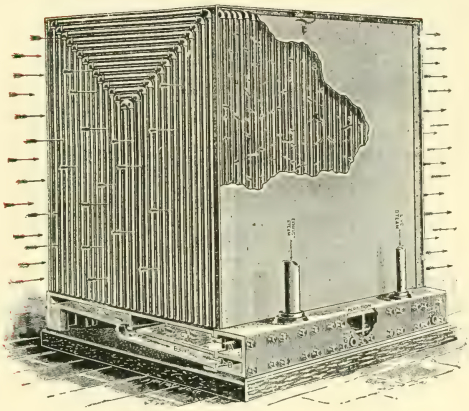
This is generally used in Textile Mills only when the space allotted is of such a shape as to preclude all possibility of placing an apparatus of the standard type. Where the space is narrow but of considerable length, it is often a very simple matter to construct the fan so as to blow the air through the heater. This makes a narrow but long apparatus of equal efficiency with the regular standard apparatus. Such an arrangement is frequently desirable where a pulley fan is to be used in place of a steam fan and it would be impossible to belt directly to a fan arranged in the regular manner. The outlet from the heater may be placed in almost any position, at the end of the heater so as to discharge either directly outward at the end, or upward, downward, to the right, or to the left. The discharge of the fan is always made so as to cause the most thorough circulation of the air passing through the heater—that is, with the discharge at the top of the heater, the fan would have a bottom horizontal discharge, while with a bottom discharge on the heater, the fan would be a top horizontal discharge.

The heater is similar to that described in the standard apparatus, and built of the proper number of sections to give the required heating surface.

We do not illustrate this type of apparatus, as we do not advise its use.

Heating and Ventilation, Continued.

Heaters.



Fan System Sectional Heater.

(Positive Steam Circulation and Drainage, Partition Header for both Live and Exhaust Steam.)

(**Buffalo.**)

The Header has two compartments, A and B. With the exception of heaters of unusual size, one header is used for the entire group of sections. Compartment A is the chamber into which steam is admitted, and through which it passes to compartment C of each manifold in supplying the heating surface. Compartment B of the header is directly underneath the steam supply. Through it passes all the water of condensation coming from the entire heater, from which (through G) it finds exit into the traps.

The Sectional Bases have three distinct compartments, C, D and E, each of ample area for the specific purpose for which it is intended to serve. From A, in the header, steam is admitted to the manifolds through chamber C, and thence passes up through the vertical pipes to and across the horizontal pipes at top of heater, and thence down the vertical pipe at opposite side, all as indicated by the arrows. Out of

Heating and Ventilation, Continued.

the manifold compartments, C and D, the condensation flows through E into header chamber B, from whence it is removed through the drip G into the trap. As the engraving clearly illustrates, there is a rapid flow to the exits provided, which are of ample area. This flow is accelerated by the inclined bottoms of the manifolds. Dry steam in every portion of the heater is positively ensured at all times. The pipes are screwed into the cast-iron bases in such a manner as to allow free expansion and without endangering the joints and inducing leaks. Each manifold, which is of ample thickness, is planed on the ends, so that when bolted to the planed surface of the header an accurate fit is secured.

Every section is independent and has a separate connection to the header or steam supply. If any section should become damaged, or a leakage occur at the joints, it may be removed without disturbing any of the others, and by capping the connection to the header, the balance of the heater may be operated while repairs are being made.

These heaters are arranged to use live and exhaust steam at the same time, or either all exhaust or all live, as desired. Each heater is thoroughly tested under a hydrostatic pressure of 150 pounds per square inch before leaving the works, ensuring tightness and perfect freedom from flows.

As above explained, the different sections of these heaters are independent in construction; they can also be made independent in action by being separated with blank flanges. This arrangement permits of complete control of the amount of heating surface in use at any one time, independent valves cutting off each section at will. Two such arrangements are shown on pages 382 and 385. This type of heater makes a very convenient and satisfactory arrangement for Southern cotton mills, where it is very seldom that the maximum amount of heating surface is really necessary for more than a day or two at a time; and where on many warm days during the winter months only heat enough is actually required to keep the mill dry and take off the chill.

Heating and Ventilation, Continued.

Dampers.

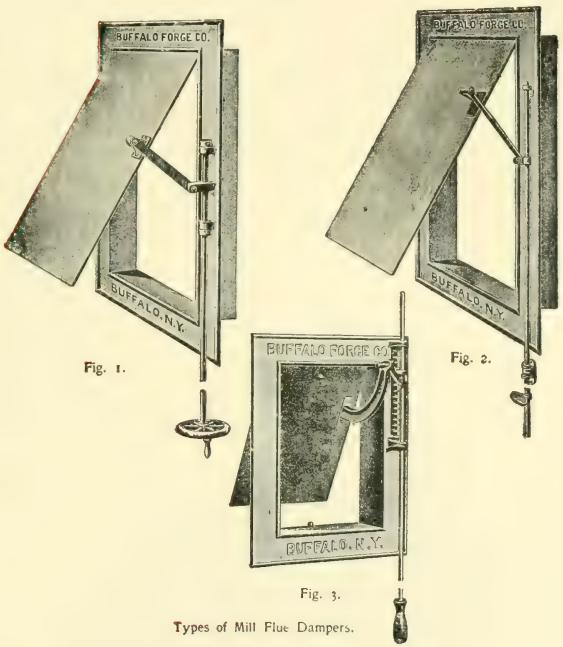


Fig. 1. Fig. 2. Fig. 3.

Types of Mill Flue Dampers.

(Buffalo.)

Fig. 1 shows a mill damper hinged at the top. A screw rod with wheel at the end extends down to a convenient position for lowering or raising. Fig. 2 shows the same damper with a sliding rod and thumb attachment of the ordinary transom style. Neither of these types obstructs the interior of the flue when the damper is open or closed. Fig. 3 illustrates a different construction of damper, with the slide extending back into the flue. This is the type always sent unless otherwise specified in order. It may be furnished with worm gear and hand wheel, if preferred. The method of fixing the position of the valve is clearly shown in the cut. Either of the two other forms illustrated may be fur-

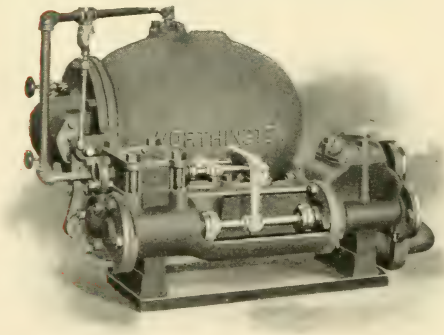
Heating and Ventilation, Continued.

nished with the same means of operating the dampers, if desired.

Standard Sizes of Dampers.

Inside dimensions of frames in inches.	Capacity in cu. ft. of air per min.	Inside dimensions of frames in inches.	Capacity in cu. ft. of air per min.
12 x 16	1066	20 x 24	2666
16 x 16	1411	20 x 30	3332
16 x 20	1777	20 x 36	4000
16 x 24	2122	24 x 24	3200
16 x 30	2666	24 x 30	4000
16 x 36	3200	24 x 36	4800
16 x 42	3722	24 x 42	5600
20 x 20	2211		

Automatic Pumps and Receivers.



The Worthington Automatic Feed Pump and Receiver.

Automatic steam pumps are widely and economically used for returning condensation from fan system heaters to boilers. If high pressure (the boiler pressure) is carried on the heating system, where coils may be sufficiently elevated

Heating and Ventilation, Continued.

above boilers and a gravity return secured, their use may be dispensed with.

Ordinary receiving steam traps are not suitable for Fan Systems, inasmuch as the action of the fan in passing air in large volumes causes very rapid condensation. The amount of water discharged from a given number of lineal feet of one-inch pipe built and used in a properly designed fan system heater, and the heating efficiency therefrom, are from three to five fold greater than when used as a direct heating coil. If a trap is used, therefore, this excess must be provided for

The main difficulty met with in any attempt to design a device for automatically controlling the speed of a pump through the level of water in a tank is to secure a reliable form of float.

The automatic arrangement illustrated on the preceding page is believed to be freer from all the defects common to this class of apparatus than any heretofore devised. As the float is an open one, the pressure of course is equal on the inside and out, so that there is no tendency to collapse. The rising and falling of this float, depending upon the level of the water in the tank, operates a balanced valve which controls the admission of steam to the pump.

Table of Sizes and Dimensions.

Number.	Size.	Amount of radiating surface it will drain.	Approximate Dimensions		
			Length.	Width.	Height.
		Sq.ft.			In.
1	3 x 2 x 3	5,000	3 ft. 1 in.	2 ft. 6 in.	23½
2	4½ x 2¾ x 4	12,500	3 ft. 3 in.	2 ft. 9½ in	23½
3	5¼ x 3½ x 5	25,000	3 ft. 9 in.	3 ft.	23½
4	6 x 4 x 6	40,000	4 ft. 2 in.	3 ft. ½ in.	23½

Note.—When using this table, do not forget it is made for direct heating coils, and for a Fan System you should not count on more than one-third to one-fifth the capacities given.

2.9 lineal feet of 1″ pipe, as ordinarily used in a Heater contain one square foot of radiating surface.

Heating and Ventilation, Continued.

Rules and Technical Data.

In General. For the proper ventilation of a cotton mill, the best practice is in favor of changing the air every twenty minutes; and so the first step in determining the proper size of a heating and ventilating apparatus is to figure out the total number of cubic feet in the building to be heated. For the basis of calculation, therefore, divide this by twenty, for the number of cubic feet of air to be handled per minute.

Size of Fan.—This depends, of course, not only upon the volume of the air to be moved, but also upon the pressure to be maintained, which regulates the velocity of the air in circulation. As to the proper pressure and velocity, there exists considerable difference of opinion, but good practice is to operate the fan at one ounce pressure. The table on page 398 gives the volume of air handled at different pressures by fans of various sizes.

The table on page 399 gives the cubical contents of the buildings that the different size fans will change once in 20 minutes.

Size of Ducts and Flues.—The term "duct" is generally applied to the horizontal air passages, and "flue" to the vertical branches taken off to the different floors.

Take from the table the number of square inches of area of the main duct; it will be found opposite the Number of Cubic Feet per Minute, and under a Velocity of 2600 Feet per Minute, corresponding to pressure of ¼ oz. The main duct area should be a little in excess of this to allow for friction. In the case of a rectangular duct, having the area required, the proposition is very simple. But in a flue quadrant in section, as shown in Fig. 1 on page 378, the proposition is a little more complicated; the radius of the quadrant, however, will be found in actual practice to be equal to the diameter of a circle of the same corresponding area. Starting from the fan outlet, make the main duct full size up to the first vertical flue; as you proceed, taper it in direct proportion to the vertical flues taken off, but increase the area a little toward the extreme ends so as not to greatly lessen the flow of air by friction. The area of the duct at the extreme ends may be in actual practice as much as double that theoretically called for. When it reaches the last flue, the velocity of the air in the duct should not be more than 1400 feet per minute, unless the ducts are very short.

Vertical flues are usually spaced forty to fifty feet apart, depending upon the width of bays in the mill; if possible,

Heating and Ventilation, Continued.

distribute them uniformly along the side of building, and so that the last ones are within one bay of each end. The velocity of the air up the flues should be between 800 and 1000 feet per minute.

The flues are also tapered off on each floor as the air is taken out through the dampers, but not uniformly, as the top story is the hardest one to heat: the area of the flue to the top story, therefore, should be at least fifty per cent. greater than theoretically called for.

Dampers.—The velocity through the dampers should be from 600 to 800 feet per minute. Select from the tables of standard sizes those which come nearest the result in area.

Heater Sections.—It will be noticed in the table on page 399 that each fan is provided for the use of four, five or six heater sections as may be required. Where the 20-minute air change is being used and the air taken from out of doors so as to give the best ventilation, in warm climates or those where the temperature really never goes below say 15 or 20 degrees above zero, five sections will be found to be ample to heat the building. In colder climates, however, where the thermometer falls as low as zero, it will be found necessary to use six sections.

In some plants it is not desired to use outside air, and in such cases the air is drawn from the building and used over and over. In these cases in warm climates four sections will be ample, or in cold climates five sections will be ample. While this practice of recirculating the air would do the heating properly, it does not give the best ventilation, as can be readily seen.

Each of these sections, except those 7′ long, contain four rows of pipe, or in other words, when there are five sections of heater the air will pass over 20 rows of pipe before reaching the fan. The 7′ sections contain two rows of pipe and it is therefore necessary to use twice the number of sections in order to provide the same number of rows for the air to pass. On fans of larger than 140″ it is necessary to use two sections set end to end in order to get sufficient area through the sections for the passage of the air. Therefore, on all heaters with 150″ fans as above, the steam supply will be taken in at each side of the heater bank.

Heating and Ventilation, Continued.

Velocity, Volume and H. P. Required When Air Under Given Pressure in Ounces per Sq. In. is Allowed to Escape into the Atmosphere.

(Sturtevant.)

Pressure in Ounces Per Square Inch.	Velocity of Dry Air at 50° Temperature Fahr. Escaping into the Atmosphere through any shaped Orifice in any Pipe or Reservoir in which the Given Pressure is Maintained.		Volume of Air in Cubic Feet which may be Discharged in One Minute through an Effective Area of Discharge of One Square Inch.	Horse Power required to move the given Volume of Air under the given Conditions.
	In Feet per Second.	In Feet per Minute.		
1/8	30.47	1828.4	12.69	0.00043
1/4	43.08	2585.0	17.95	0.00122
3/8	52.75	3165.1	21.98	0.00225
1/2	60 90	3653.8	25.37	0.00346
5/8	68.07	4084.0	28.36	0.00483
3/4	74.54	4472.6	31.06	0.00635
7/8	80.50	4829.7	33.54	0.00800
1	86.03	5161.7	35.85	0.00978

Revolutions of Fan Wheel of Given Diameter

Necessary to Maintain a Given Pressure over an Area which is within the Capacity of the Fan.

(Sturtevant.)

Diameter of Fan Wheel in Feet.	Pressure in Ounces per Square Inch.							
	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1
5	116	164	202	232	260	285	308	329
5½	106	149	183	211	236	259	280	299
6	97	137	168	194	217	238	256	274
7	83	117	144	166	186	203	220	235
8	73	103	126	146	163	178	192	205
9	65	92	112	129	144	158	171	183
10	58	82	101	116	130	142	154	164
12	49	69	84	97	108	119	128	137
14	42	59	72	83	93	102	110	117
15	39	55	67	78	87	95	102	110

Heating and Ventilation, Continued.

Steel Plate Fans.

With three-quarter Housings.

(Sturtevant.)

Fans with three-quarter steel-plate housings have the upper portion built of steel plate well braced with angle iron, of which the foundation frame is also constructed. The lower portion is constructed of brick in the manner shown in the accompanying cuts and thereby completes the entire fan. The top of this brick foundation is usually surmounted by a heavy wooden frame to which the steel-plate housing is lag-screwed, and which in turn is securely anchor-bolted to the brick work.

Size.	Outside Diameter of Inlet in inches.	Outside Dimensions of Outlet in inches.	Diameter and Face of Pulley in inches.	Size of Direct Connected Horizontal Engine.	Ordinary No. of Revolutions per Minute.	Size of Pipes on Engine in inches.	
						Steam.	Exhaust
5 x2⅔	42⅜	33½ x 33½	20x 8½	6 x 6	330	2	2½
5½x3	47	37¾ x 37¼	22x 9½	6 x 6	300	2	2½
6 x3½	52¼	42½ x 42½	24x10½	6 x 9	275	2	2½
7 x4	60½	48½ x 48½	28x12½	7 x10½	235	2½	3
8 x4	68½	48½ x 54½	32x12½	8 x12	205	2½	3
9 x4½	77	54¾ x 60¾	36x12½	9 x12	185	3	3½
10 x5	85½	60¾ x 72¾	42x12½	10 x12	165	3	3½
12 x6	102½	72¾ x 84¾	48x14½	11½x16	140	3	3½
14 x7	120	84¾ x 96¾	54x14½	12 x24	120	4	5
15 x7½	128½	90¾ x102¾	60x16½	14 x24	110	5	6

Note.—The horizontal engines may be either right or left hand; that is, with the shaft extending to either the right or the left as one stands at the cylinder and looks toward the crank. The sizes here given are those necessary to attain the ordinary speed, under the usual conditions, with a steam pressure of about eighty pounds. For other steam pressures or speeds, engines of other sizes are applied.

Flue Area Required

For the Passage of a Given Volume of Air at a Given Velocity.

(Sturtevant.)

Volume in Cubic Feet per minute	Velocity in Feet per Minute.																	
	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2600
100	18	16	14	13	12	11	10	9.6	9.	8.5	8	7.6	7.2	6.9	6.6	6.3	6.	5.5
125	23	20	18	16	15	14	13	12.	11.3	10.6	10	9.5	9.	8.6	8.2	7.8	7.5	6.9
150	27	24	22	20	18	16	15	14.4	13.5	12.7	12	11.4	10.8	10.3	9.8	9.4	9.	8.
175	32	28	25	23	21	19	18	16.8	15.8	14.8	14	13.3	12.6	12.	11.5	11.	10.5	9.7
200	36	32	29	26	24	22	21	19.2	18.	16.9	16	15.2	14.4	13.7	13.1	12.5	12.	11.1
225	41	36	32	29	27	25	23	21.6	20.3	19.1	18	17.1	16.2	15.6	14.7	14.1	13.5	12.5
250	45	40	36	33	30	28	26	24.	22.5	21.2	20	19.	18.	17.1	16.4	15.7	15.	13.9
275	50	44	40	36	33	30	28	26.4	24.8	23.3	22	21.8	19.8	18.9	18.	17.2	16.5	15.2
300	54	48	43	39	36	33	31	28.8	27.	25.4	24	22.7	21.6	20.6	19.6	18.8	18.	16.6
325	59	52	47	43	39	39	33	31.2	29.3	27.5	26	24.6	23.4	22.3	21.3	20.6	19.5	18.
350	63	56	50	46	42	39	36	33.6	31.5	29.6	28	26.5	25.2	24.	22.9	21.9	21.	19.4
375	68	60	54	49	45	42	39	36.	33.8	31.8	30	28.4	27.	25.7	24.5	23.5	22.5	20.8
400	72	64	58	52	48	44	41	38.4	36.	33.9	32	30.3	28.8	27.4	26.2	25.	24.	22.2
425	77	68	61	56	51	47	44	40.8	38.3	36.	34	32.2	30.6	29.1	27.8	26.6	25.5	23.5
450	81	72	65	59	54	50	46	43.2	40.5	38.1	36	34.1	32.4	30.9	29.5	28.2	27.	24.9
475	86	76	68	62	57	53	49	45.6	42.8	40.2	38	36.	34.2	32.6	31.1	29.7	28.5	26.3
500	90	80	72	65	60	55	51	48.	45.	42.4	40	37.9	36.	34.3	32.7	31.3	30.	27.7

Note.—For flue areas corresponding to larger volumes than shown above: For 800 feet, double that given for 400 feet; for 1500 feet, multiply by three that given for 500 feet, etc. The areas given are in square inches.

Sizes of Fans, Engines and Heaters.

For a Given Cubic Space to Be Heated and Ventilated.

(Buffalo)

Size of Fan.	Cubic Feet of Space Fan will Supply at 20 Min. Air Change.	Fan.					Engine.		Heater.	Approx. Boiler H. P. Required for Heater Using Air from Outside.			Size of Steam Main for Heater Using 6 Secs.
		Dia. of Inlet.	Size of Outlet.	Size of Pulley.	Speed R. P. M.	Approx H. P.	Size at 80 lbs. Press.	Type of Engine.	Length and Height of Sec.	4 Sec.	5 Sec.	6 Sec.	
50	107200	24¼	18½	4 x 9	548	3	4 x 4	Vert.	3′x4′- 4″	12	15	18	2½″
60	160400	26⅞	22¼	5 x 10	459	4	4 x 4	"	3′x4′-10″	14	18	20	2½″
70	220800	34⅛	26	5 x 11	394	6	4 x 4	"	3′x5′-10″	17	22	26	3 ″
80	280000	39½	29¾	6 x 12	346	7	5 x 5	"	4′x5′-10″	22	27	33	3½″
90	360000	43¼	33½	6 x 14	308	9	5 x 5	"	4′ 6″x6′-4″	27	34	40	3½″
100	470000	46¼	37½	7 x 16	278	11	6 x 6	"	5′x6′-10″	32	40	48	4 ″
110	550000	51¾	41	7 x 18	252	13	6 x 7	"	5′x7′-10″	38	48	56	4 ″
120	680000	55	44¾	8 x 20	232	16	7 x 7	"	6′x7′ 10″	44	56	67	4½″
130	790000	60¾	48½	8 x 22	214	18	7 x 7	"	6′x8′-10″	51	64	76	5 ″
140	928000	64¾	52¼	9 x 24	199	21	8 x 8	Hor.	7′x8′-10″	60	75	92	2-4 ″
150	1063000	69½	56	10 x 26	186	24	8 x 10	"	*2-5′-0″x6′-10″	65	80	97	2-4 ″
160	1222000	74	59¾	11 x 28	174	28	8 x 10	"	*2-5′-0″x7′ 10″	76	96	112	2-4 ″
170	1392000	79¼	63⅝	12 x 30	164	31	9 x 10	"	*2-6′-0″x7′-10″	88	112	134	2-4½″
180	1554000	84	67¼	13 x 32	155	35	10 x 10	"	*2-6′-0″x8′-10″	102	128	152	2-5 ″
190	1760000	88½	71	14 x 34	148	40	10 x 12	"	*4 5′-0″x8′ -0″	120	150	180	4-4 ″
200	1978000	92½	74¾	15 x 36	140	45	11 x 12	"	*4 7′-0″x8′-10″	126	158	190	4-4 ″

* Sections placed back to back.

Sections under 7′-wide are 4 row sections. Sections 7′-wide are 2 row sections.

Heating and Ventilation, Continued.

Steel-Plate Fans.

(Speed of fans and volume of air in cubic feet per minute delivered into buildings at various pressures in ounces per square inch.)

(Buffalo.)

Size of Fan in inches.	¼ oz. Pressure. 2585 Vel.		½ oz. Pressure. 3653 Vel.		¾ oz. Pressure. 4472 Vel.		1 oz. Pressure 5175 Vel.	
	Rev.	Vol.	Rev.	Vol.	Rev.	Vol.	Rev.	Vol.
50	276	2690	388	3800	475	4660	548	5360
60	230	4190	325	5920	398	7250	459	8320
70	197	5690	280	8040	342	9840	394	11340
80	173	7240	245	10210	300	12500	346	14450
90	154	9180	218	12950	267	15850	308	18300
100	139	11770	197	16610	240	20350	278	23500
110	127	14000	179	19750	219	24200	252	27950
120	116	17150	164	24200	201	29700	232	34300
130	107	19780	152	27900	186	34200	214	39500
140	100	23210	141	32800	173	40200	199	46400
150	94	26650	132	37700	162	46150	186	53200
160	88	30600	124	43250	151	53000	174	61100
170	82	34100	116	48100	142	59000	164	68100
180	78	38900	110	55000	135	67400	155	77700
190	74	44100	104	62300	128	76300	148	88000
200	70	49500	99	70000	121	85700	140	98900

Heating and Ventilation, Continued.

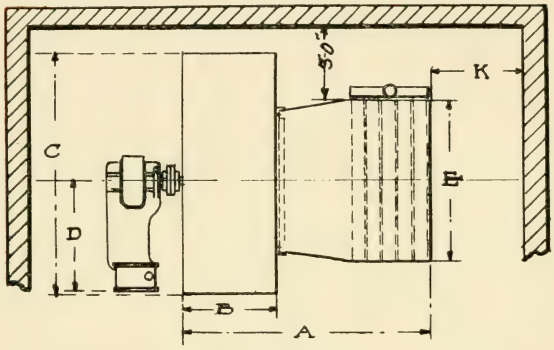
Diagrams and Tables of Dimensions.

The arrangement and disposition of heating and ventilating apparatus varies greatly according to local conditions. It is therefore out of the question in this book to furnish diagrams and tables that would suit all cases.

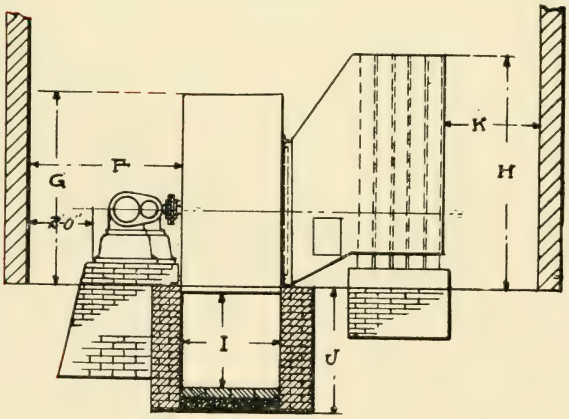
At the same time, realizing that for estimating purposes in particular, it is very desirable to have something to work from, I have attempted on page 397 to compile a table of Standard Sizes of Apparatus. This, taken in conjunction with the Diagrams and Tables of Dimensions given on the following four pages, will be found sufficient for most purposes.

The Table of Standard Sizes applies to any type of fan; the Diagrams and Tables of Dimensions, however, apply only to three-quarter housing apparatus, which is what we recommend whenever circumstances will permit its use.

Heating and Ventilation, Continued.



Floor Plan.



Elevation.

Diagrams of Buffalo Apparatus.

(Three-quarter Housing, Engine-driven, Fan.

Heating and Ventilation, Continued.

Table of Lettered Dimensions.

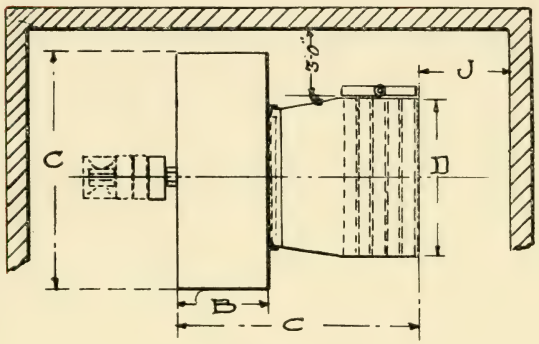
(In Inches.)

Buffalo Apparatus, Three-quarter Housing, Engine Driven Fan.

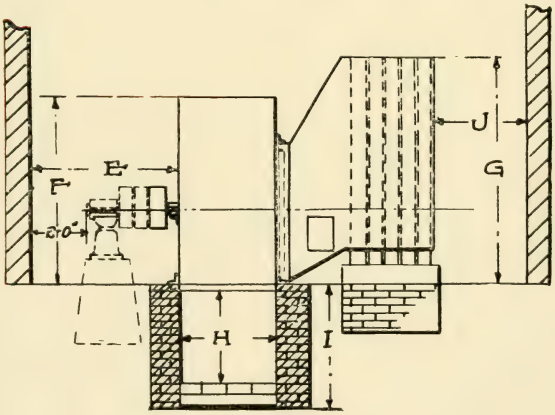
Size of Fan.	A	B	C	D	E	F	G	H	I	J	K	Size of door necessary to take app. in building.
50	85 3/8	18 7/8	46		37 1/4	38 15/16	38 5/8	59	18 1/2	29 1/2	18	3′-0″ x 4′-0″
60	88 1/8	22 5/8	55 1/4		37 1/4	38 15/16	44 1/16	65	22 1/4	33 1/4	18	3′-6″ x 5′-0″
70	95 7/8	26 1/8	64 1/2		37 1/4	43 5/16	53 7/8	77	26	37	18	4′-0″ x 6′-0″
80	99 5/8	30 1/8	73 3/4		47 5/8	43 5/16	60 3/8	77	29 3/4	40 3/4	24	4′-3″ x 7′-0″
90	103 3/4	33 3/4	83		47 5/8	43 5/8	67	83	33 1/2	44 1/2	24	5′-0″ x 7′-0″
100	110	37 1/2	92 3/4		57 5/8	65 1/8	73 5/8	89	37 1/4	48 1/4	30	5′-0″ x 8′-0″
110	113 3/4	41 1/4	101 1/2		57 5/8	65 3/4	81	101	41	52	30	6′-0″ x 8′-0″
120	117 1/2	45	110 3/4		68 1/4	69 1/2	87 1/4	101	44 3/4	55 3/4	36	6′-0″ x 8′-0″
130	127 5/8	48 7/8	120	55	68 1/4	70 7/16	95 1/2	113	48 1/2	59 1/2	36	6′-6″ x 9′ 0″
140	131 1/8	52 5/8	129 1/4	55	83 1/2	71 1/16	102 5/8	113	52 1/4	63 1/4	36	7′-0″ x 9′-0″
150	134 7/8	56 3/8	138 1/2	65	123 1/2	76 1/16	109 1/2	89	56	67	42	8′-0″ x 10′-0″
160	144 5/8	60 1/8	147 3/4	65	123 1/2	77 1/16	116 1/2	101	59 3/4	70 3/4	42	8′-0″ x 10′-0″
170	148 3/8	63 7/8	157	65	144 1/4	77 1/16	124 1/2	101	63 1/2	74 1/2	48	9′-0″ x 11′-0″
180	158 1/8	67 5/8	166 1/4	65	144 1/4	79 1/16	131 5/8	113	67 1/4	78 1/4	48	9′-0″ x 12′-0″
190	161 7/8	71 3/8	175 1/2	81 3/4	174 7/8	85 1/16	138 3/4	107	71	82	60	9′-0″ x 12′-0″
200	165 5/8	75 1/8	184 3/4	81 3/4	174 7/8	85 1/16	145 7/8	113	74 3/4	85 3/4	60	10′-0″ x 12′-6″

(To accompany diagrams on opposite page.)

Heating and Ventilation, Continued.



Floor Plan.



Elevation.

Diagrams of Buffalo Apparatus.

(Three-quarter Housing, Pulley-driven, Fan.)
(Also Three-Pulley Rig.)

Heating and Ventilation, Concluded.

Table of Lettered Dimensions.

(In Inches.)

Buffalo Apparatus, Three-quarter Housing, Pulley Driven Fan.

Size of Fan.	A	B	C	D	E 1 Pulley.	E 3 Pulley.	F	G	H	I	J	Size of Door Necessary to take App. in Building.
50	85 5/8	18 5/8	46	37 1/4	33 13/16	41 3/16	38 3/8	59	18 1/2	29 1/2	18	3′-0″ x 4′-0″
60	88 1/8	22 5/8	55 1/4	37 1/4	34 1/16	44 1/8	41 1/16	65	22 1/4	33 1/4	18	3′-6″ x 5′-0″
70	95 7/8	26 1/8	64 1/2	37 1/4	35 5/16	47 1/16	53 1/8	77	26	37	18	4′-0″ x 6′-0″
80	99 5/8	30 1/8	73 3/4	47 5/8	35 5/16	59 1/8	60 3/8	77	29 3/4	40 3/4	24	4′-3″ x 7′-0″
90	103 1/4	33 3/4	83	47 5/8	36 5/8	60 7/8	67	83	33 1/2	44 1/2	24	5′-0″ x 7′-0″
100	110	37 1/2	92 1/4	57 7/8	37 5/8	63 3/8	73 5/8	89	37 1/4	48 1/4	30	5′-0″ x 8′-0″
110	113 3/4	41 1/4	101 1/2	57 7/8	38 1/2	64 1/2	81	101	41	52	30	6′-0″ x 8′-0″
120	117 1/2	45	110 3/4	68 1/4	38 1/2	67 1/2	87 1/4	101	44 1/4	55 3/4	36	6′-0″ x 8′-0″
130	127 3/8	48 7/8	120	68 1/4	40 1/16	68 1/16	95 1/2	113	48 1/2	59 1/2	36	6′-0″ x 9′-0″
140	131 1/8	52 5/8	129 1/4	83 1/2	41 5/16	69 1/16	102 5/8	113	52 1/4	63 1/4	36	7′-0″ x 9′-0″
150	134 7/8	56 1/2	138 1/2	123 1/2	43 1/16	73 1/8	109 1/2	89	56	67	42	8′-0″ x 10′-0″
160	144 5/8	60 1/8	147 3/4	123 1/2	44 1/16	76 1/16	116 1/2	101	59 3/4	70 3/4	42	8′-0″ x 10′-0″
170	148 3/8	63 7/8	157	141 1/4	45 11/16	79 1/16	124 1/2	101	63 1/2	74 1/2	48	9′-0″ x 11′-0″
180	158 1/2	67 5/8	166 1/4	141 1/4	46 1/2	84 1/16	131 5/8	113	67 1/4	78 3/4	48	8′-6″ x 12′-0″
190	161 7/8	71 3/8	175 1/2	174 3/4	47 5/16	87 1/16	138 3/4	107	71	82	60	9′-0″ x 12′-0″
2 0	166 5/8	75 1/8	184 3/4	174 3/8	48 5/16	90 1/16	145 7/8	113	74 3/4	85 3/4	60	10′ x 12′-0″

(To accompany diagrams on opposite page.)

*MILL FIRE PROTECTION.

Cotton is extremely sensitive to fire from causes that do not have similar effect upon other materials, consequently as it passes through all the various processes of manufacture it must be safeguarded with every possible feature of protection available. This fact has been recognized by manufacturers in the selection of a better type of construction and fire protection than is used in almost all other arts. The result is that this hazardous class has been made so safe as to reduce the fire cost below that of other ordinarily considered safer kinds of business.

Building Construction.

The mill itself should be built of brick "**Standard Mill Construction,**" that is, heavy wooden columns or "posts," solid bay timbers and heavy plank floors with top dressing of good wearing hard wood. The use of built up bay timbers with intermediate space between is very undesirable.

The stairways and elevators should be in brick towers with fire doors at entrance to mill and self closing hatches on the elevator. The belt way or rope drive should be cut off by brick walls, power being conveyed by the shafting through a tight collar.

The pickers should be located in a portion cut off from all other processes by fire walls extending through the roof. The waste picker if any should be in a separate brick compartment, preferably a one-story addition adjoining the picker house yet having a fire door communicating with it.

Where colored goods are manufactured the dye house should be in a separate building, entirely detached or in a wing cut off from the mill by fire separation. The dye house should be equipped with sprinklers under the dry pipe system so that it will not be necessary to shut water off in cold weather. The raw stock drying machines ordinarily used in connection with the dye house processes should be placed in a separate room surrounded by a brick wall, having fire doors at opening into dye house. Automatic sprinklers should be placed inside the dryers as well as in the room in which the dryers are located.

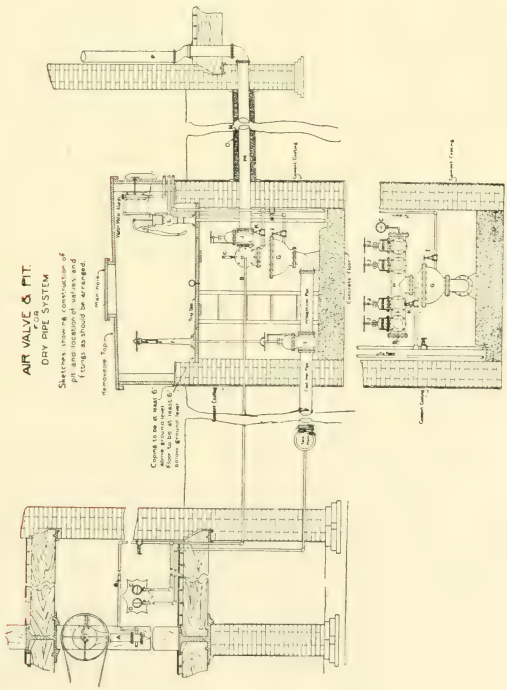
Cloth room should be in a one-story wing, properly cut off, by which means the cloth is not subjected to fire, water or smoke damage of the manufacturing plant.

* I am indebted to Mr. W. H. Stratton for much valuable data on this subject, particularly for Factory Insurance Association requirements.

Mill Fire Protection, Continued.

Cotton Warehouses.

The warehouses should be equipped with automatic sprinklers under the **dry pipe system with air valve with pit outside**, thus affording continuous protection and making it unnecessary to shut water off sprinklers in winter, a practice followed in some localities but being a very objectionable one owing to the fact that the cotton is left without protection and the mill is thus likely to be deprived of a supply with which to operate. The following diagram shows such an equipment:



Mill Fire Protection, Continued.

Cotton should be stored in standard warehouses detached at least 100 feet from the mill, thus giving plenty of space in which to fight cotton fire as the burning bales are taken from the warehouse.

The storehouses should be one story, cement floor, "standard mill construction;" that is, heavy wooden posts, heavy bay timbers, plank roof covered with gravel or tin, having good spark proof ventilators, at least a 16″ fire wall separation between sections passing three feet above the roof, compartments not to exceed 50x100 ft. in size. Cotton should be stored one bale high on end, thus making it easier to handle and affording better opportunity for water from sprinklers to surround the bales.

A recent arrangement by which cotton is opened by hand in a small compartment adjoining the storehouse, yet separated from it by a fire wall, with openings only on the outside and from which cotton is conveyed by a blower system to the picking department proper, is a step toward further safety from fire.

All openings in division walls should be fitted with automatic sliding fire doors, made up of three thicknesses of well seasoned white pine, nailed with clinched nails and covered with double locked jointed I. C. tin, nailed under seams Solder should not be used on fire doors, nor should nail heads be exposed. The fire doors should be hung on standard track, bolted through the wall and provided with all necessary fittings, such as chafe irons, guides, handles, shoes, etc.

Oil and Waste Houses.

A separate outside brick building should be provided for storage of oil in barrels and never more than one barrel of oil should be kept in the mill at one time this being contained in a metal cabinet located preferably in the engine room.

A similar house should be provided for the storage of waste.

Mill Fire Protection, Continued.

*The Equipment.

A standard installation includes all the following items :

(1) **Automatic Sprinklers** inside the building.

A standard equipment of approved automatic sprinklers should be provided through all portions, including basements, towers and offices, to be arranged according to the universal schedule of pipe sizes and spacing. Where so much reliance is placed upon the automatic sprinklers it is very necessary that only the best devices shall be used ; it is equally essential that the work of installing the sprinklers should be carried on only by experienced contractors familiar with the work and the rules governing it. It should not be done by a local plumber with only a hazy idea of the business who purchases the sprinklers and other apparatus and who does not feel any particular responsibility in the work.

Sprinklers should always be placed in the conveyor trunks of pickers where they stop many a fire that would otherwise gain headway and cause serious damage.

Always have at least a dozen extra sprinklers on hand for use in case of accident or after small fire, or for sprinkling small additions or closets as soon as built.

Never have service connections to sprinkler pipes, sprinkler tanks or any other fire protection apparatus because this use introduces sediment, causes corrosion and may result in using up the entire water supply so that when the fire comes there is no water available. The fire protection equipment should be left intact for the special purpose for which it is installed.

The present requirements for feeding the sprinkler system are as follows: There shall be a separate riser in each building and in each section of the building divided by fire walls ; it shall be of sufficient size to supply all the sprinkler heads on any floor in each section. These risers are to be connected to the sprinkler tank by means of an outside line of cast iron pipe situated at from 40 to 60 feet from the building ; each riser and main from the sprinkler tank are to be cut off outside the building by gate valves with indicator posts This whole outside system of sprinkler piping is to be connected to the Underwriters pump direct or to the hydrant system with a suitably placed check valve and post indicator gate valve.

* I am indebted to the General Fire Extinguisher Co. for many of the details embraced under this heading.

Mill Fire Protection, Continued.

Spacing of Sprinklers.—Under Mill Ceiling (smooth solid plank and timber construction, 6 to 12 feet bays)—one line of sprinklers should be placed in center of each bay and distance between the sprinklers on each line should not exceed the following:

7 to 8 feet in 12 feet bays (measuring center to center of timbers).

8 to 9 feet in 11 feet bays (measuring center to center of timbers).

10 feet in 6 to 10 feet bays (measuring center to center of timbers).

Under Joist Ceiling, Open Finished—Distance between sprinklers not to exceed 7 to 8 feet at right angles with joists or 9 to 10 feet parallel with joists. Sprinklers on alternate lines should be staggered.

Bays formed by timbers which support the joists, if from 10 to 11½ feet wide from center to center of timbers, may, by special permission, have but one line of sprinklers, if the conditions warrant. In all cases where such bays are over 11½ feet wide, two or more lines of sprinklers must be installed as required by the standard.

Size of Pipes.—In no case shall the number of sprinklers on a given size pipe exceed that marked "A" in the following table.

Schedule for "branch lines," where more than six sprinklers are on one "branch line;" after passing the sixth sprinkler the pipe schedule shall apply to the next larger size of piping, as given under heading "B" in the following table.

Size of Pipe.	Maximum Number of Sprinklers Allowed.	
	"A"	"B"
¾ inch	1	1
1 "	2	2
1¼ "	4	4
1½ "	8	6
2 "	16	8
2½ "	28	16
3 "	48	28
3½ "	78	..
4 "	110	..
5 "	150	..
6 "	200	..

Furthermore no feeder to any such "branch line" shall be smaller than said "branch line."

Mill Fire Protection, Continued.

(2) **A sprinkler tank** to hold not less than 12,000 to 15,000 gallons, connected by means of a 6-inch pipe with indicator or indicator post valves to the sprinkler system. The bottom of the tank should be elevated at least 15 feet above highest line of sprinklers. This tank should be reserved exclusively for automatic sprinklers and should not have any mill service connections taken from it nor should it be used to supply the hydrants.

The practice of providing a larger tank of say 50,000 gallons capacity and also connecting it to the hydrants is not recommended by the Factory Insurance Association for the reason that the elevation is not sufficient to give satisfactory and effective hose streams and the water thus used in the hose streams is only taken away from the sprinklers and also reduces the pressure in a similar degree. It is proper to state, however, that the Factory Mutuals make a point of having this large tank elevated outside the mill, preferably on an iron or steel structure, as shown on page 414. Tank should have tell-tale and should be protected against freezing.

In lieu of sprinkler tank a reservoir is sometimes erected on the side of a hill; any such arrangement is entirely satisfactory provided it is sufficiently elevated to give the required water pressure on the highest sprinkler. Occasionally the mill people are allowed to connect with the city mains, and if the water pressure is sufficient this is generally also acceptable to the insurance people.

(3) **A duplex steam Underwriter pump** or a rotary power pump driven from the main jack shaft of a water wheel by iron friction gearing.

As secondary supply, the Underwriter steam fire pump should be ordinarily of 1,000 gallons capacity per minute. It should be connected up to a **Priming Tank** of at least 300 gallons capacity. This pump should be built in accordance with the revised 1903 Underwriter specifications and should be fitted with sight feed lubricator, hand oil pump and steam trap. The main throttle should be placed in a horizontal piece of pipe directly at the pump and the steam feed should be arranged so that the pipe will drain up to the throttle and all condensation thus carried away through the trap.

The **hose connections** should be extended outside the pump house and provided with hose house, thus serving as a hydrant.

The boiler house should be separated from all other portions of the mill by brick fire wall extending above the roof

Mill Fire Protection, Continued.

and having fire doors at opening to engine house. As the fire pump depends upon the boilers for steam it is absolutely necessary that it shall be thus separated from the rest of the risk. Proper controlling valves should be provided in the steam connections in boiler house so that the entire steam supply may be cut off from all other uses and reserved wholly for the fire pump.

The fire pump should be placed in a separate building adjoining the boiler house and not connecting with any other building. 50 lbs steam pressure of a volume sufficient to run pump to full capacity should be maintained on the boilers at all times.

The use of a rotary pump for fire services is not recommended except in extreme cases where sufficient boiler capacity to run a steam fire pump will not be available and even in such cases it is recommended that the rotary pump shall be supplemented by a steam pump provided with a quick steaming boiler as the final resource in event of fire. The rotary pump is a treacherous machine, cannot be easily governed, is usually located in damp, dark places difficult of access and requires constant lubrication Where used it should be connected in such a way that it can be run independent of mill shafting.

The supply for fire pumps should be from as inexhaustible a source as possible, otherwise a separate reservoir should be used, the capacity to be limited only by the surroundings and the expense involved. Under ordinary conditions a reservoir supply of at least 200,000 gallons should be maintained and where cotton storage is involved the supply should be unlimited in view of the fact that cotton fires often burn for days, thus necessitating constant use of hose streams for that length of time. For small mills a minimum supply in special cases has been allowed on a basis of 100 minutes supply for the Underwriter pump.

The end of suction should be fitted with foot valve and strainer and should extend into a pocket in reservoir so that all water can be withdrawn. The suction should be laid on a gradual incline to pump, thus avoiding air pockets. Furthermore, the Underwriter pump will not lift water satisfactorily over 12 or 15 ft., hence excessive lift should be avoided.

Mill Fire Protection, Continued.

The Underwriter pump is to be supplied with a priming tank of 300 gallons capacity connected to the priming pipe of the pump. The piping for the steam end of the pump shall be so put in as to leave a leg to catch the water of condensation which shall be trapped off with a small steam trap. The pump connection to the hydrant system shall have an indicator gate valve.

The Underwriter Fire Pump should be connected up so it can be used to feed the boilers in case of an emergency, and it should take steam direct from the steam drum at boilers.

An independent water wheel is recommended to drive the dynamos and rotary fire pump.

(4) **Outside fire hydrants** connected up with cast iron pipe, the smallest diameter of which shall be 6 inches, and shall weigh not less than 32 pounds to the lineal foot. For extra heavy pressures an additional thickness of piping is required.

The underground mains should be of cast iron, bell and spigot ends, best quality American Water Works Standard and after being laid should be subjected to 150 pounds water pressure for at least two hours, during which time hydrants and valves should be opened and closed so as to approximate conditions which would prevail during an actual fire. Do not use wrought iron or cement lined pipe under ground.

The outside protection should be from hydrants placed at least 50 ft. from the building and spaced about 150 to 200 ft. apart around the property. Hydrants should be of the new 1902 "National Standard" of the 3-way pattern, with hose valves attached to each outlet. Do not use the so-called "independent" gate hydrant with gates for each outlet inside the hydrant.

All wrench heads on indicator posts and hydrants should be of the same size and pattern, preferably 1¼" square.

Each hydrant should have a standard hose house built over it, supplied with a complete equipment of hose, play pipes, spanners, axes, bars, lanterns, hydrant wrenches, and rope for pulling hose up ladders, all as described and illustrated on page 425.

Mill Fire Protection, Continued.

(5) **A suitable watchman's time detector** is also essential to a proper system of fire protection, of which there are several kinds, electrical and mechanical. See page 427.

In General.

Where **city water of at least 60 lbs.** pressure is available through 6″ or 8″ pipe, a connection to the mill fire protection system would be advisable, but as such a supply is outside the control of the mill authorities it should not be allowed to take the place of the independent tank but should be considered as a reserve supply.

A generous supply of fire pails should be provided, as many fires are put out in their incipiency by the use of these pails. One should be hung on each post throughout the mill, while in the picker room casks of water should also be provided in addition. These pails should be galvanized iron, painted and marked for fire only and should be kept full of water at all times.

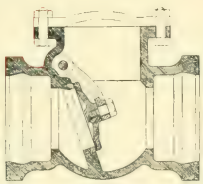
The foregoing apparatus represents a very large outlay of money and in order that the equipment may be used understandingly and so that full return may be obtained from the money invested, **a private fire brigade** should be organized among the employees and regular drills at stated intervals should be held, during which time pump should be started, the hose coupled to hydrant, the water turned on, the streams carried to the roof or into the building and all conditions made to approximate actual fire as near as possible. In connection with this certain fire signals should be arranged for, to be sounded on the mill whistle.

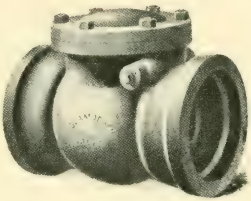
Whenever a property is shut down nights, Sundays or holidays or any other time, **a watchman** should be employed to make regular hourly rounds of the entire property and an approved time detector should be used by him in registering these rounds, the stations being placed so that every portion of the mill will be visited.

Too much care cannot be given to the cleanliness of the mill as better results are always obtained where care is observed in this respect. The property should be swept and cleaned at regular intervals and all waste should be removed as soon as gathered from the mill to a separate detached building, usually of light frame construction. For oily waste, metal safety cans should be provided but these cans should be emptied every night and the contents should be taken to the boiler house and burned.

Mill Fire Protection, Continued.

Valves.

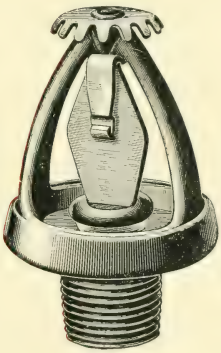


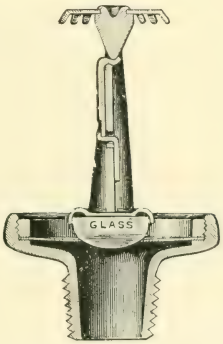


All valves in "risers" should be of the **Indicator pattern**; they should be made accessible by permanent ladders or platforms so they can be promptly reached in case of an accident or before unnecessary damage is created after a small fire.

All **check valves** should be of the swinging type, with all metal ground valves and seats.

"Grinnell" Automatic Sprinklers.



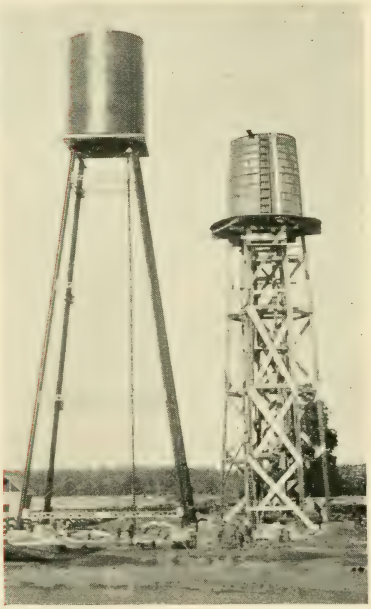


The best known and probably most reliable Sprinkler is the "Grinnell" with glass disc valve.

The peculiar and distinctive feature of this Sprinkler is that the valve is seated on a flexible diaphragm, and is so securely and ingeniously held in position as to relieve the low-fusing solder of nearly all strain.

Mill Fire Protection, Continued.

Steel Tanks and Towers.



New Steel Tower and Tank.
Height to top of Tank, 90 ft. Capacity of Tank, 25,000 gallons.
(Also showing the wooden structure which had been in use only 6 yrs.)

A Standard Tower (shown above) is composed of four "Z" bar columns, with struts made of angle and flat bar iron; lateral braces of round iron, with forged turn-buckle adjustment. On top of each column is riveted a

Mill Fire Protection, Continued.

heavy steel plate, and to these there are riveted and bolted heavy steel "I" beams. On top of the large "I" beams, and at right angles thereto, are riveted a number of smaller "I" beams, of sufficient size and number to support the tank when filled with water. The tank is made of mild homogeneous steel, and is provided with the necessary openings for water connection.

Wrought-iron ladders extend from top of tank to within ten feet of the ground, and on inside of tank from top to bottom. Suitable foundation bolts and washers for anchoring tower to foundations are included; also plans and necessary instructions for the proper construction of foundations.

While in a number of instances the use of **elevated tanks on towers** can be taken advantage of for one source of supply in an equipment for mill fire protection, still, however, in a large majority of cases it is much more convenient and satisfactory, as well as quite as cheap, to run up the **main stair tower to the mill a sufficient height to place the tank in it**—the regulation height, 15 feet above the topmost sprinkler.

In some instances they have been found so arranged that all water for general use is first pumped into the sprinkler tank, then overflows into the daily service tank. It is claimed for this arrangement that it insures the sprinkler tank being always full, but the possibility of depositing sediment in the sprinkler tank and pipes would seem to outweigh the advantages thus claimed. Greater security can be obtained by reserving the sprinkler tank exclusively and independent from all other service, and providing proper tell-tale and usual precautions for keeping it full.

Mill Fire Protection, Continued.

Steel Tanks.

(For Sprinkler and Other Purposes.)

Diameter. Feet.	Height. Feet.	Weight.	Thickness of Metal.		Gallons.
			Sides.	Bottom.	
4	4	320	No. 12	No. 12	375.9
5	4	493	10	10	587.4
5	5	581	10	10	734.2
5	6	674	10	10	881.1
6	5	779	10	10	1056.9
6	6	961	10	8	1268.6
6	8	1175	10	8	1691.5
7	7	1287	10	8	2014.6
8	8	1913	8	8	3007.0
8	10	2263	8	8	3759.0
10	8	2605	8	8	4699.8
10	10	3040	8	8	5874.8
10	12	3619	8	8	7049.7
12	10	4014	3/16″ and No. 8	3/16″	8459.1
12	12	4517	3/16″ and No. 8	3/16″	10150.9
12	15	5336	3/16″ and No. 8	3/16″	12688.3
14	14	6000	3/16″ and No. 8	3/16″	16116.9
15	15	8827	1/4″ and 5/16″	1/4″	19825.7
15	18	9957	1/4″ and 5/16″	1/4″	23790.8
15	20	10908	1/4″ and 5/16″	1/4″	26434.3
16	20	11785	1/4″ and 5/16″	1/4″	30069.6
18	15	11276	1/4″ and 3/16″	1/4″	28543.6
18	18	12500	1/4″ and 3/16″	1/4″	34252.4
18	20	13519	1/4″ and 3/16″	1/4″	38058.2
20	15	13858	1/4″ and 3/16″	1/4″	35242.0
20	20	15414	1/4″ and 3/16″	1/4″	46989.3
21	20	16358	1/4″ and 3/16″	1/4″	51806.4

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434. (Approximately, every foot elevation is considered equal to one-half pound pressure per square inch.)

To find the velocity in feet per minute necessary to discharge a given volume of water in a given time, multiply the number of cubic feet of water by 144, and divide the product by the area of the pipe in inches.

Mill Fire Protection, Continued.

Table of Capacities of Tanks and Reservoirs.

Diameter.	Circum.	Area.	Gallons 1 foot in depth.	Diameter.	Circum.	Area.	Gallons 1 foot in depth.
5.	15.71	19.635	147.26	21.	65.97	346.361	2597.70
5.5	17.28	23.758	178.18	22.	69.11	380.134	2851.00
6.	18.85	28.274	212.05	23.	72.25	415.477	3116.07
6.5	20.42	33.183	248.87	24.	75.39	452.390	3392.92
7.	21.99	38.484	288.63	25.	78.54	490.875	3681.56
7.5	23.56	44.178	331.33	26.	81.68	530.930	3981.97
8.	25.13	50.265	376.98	27.	84.82	572.557	4294.17
8.5	26.70	56.745	425.58	28.	87.96	615.754	4618.15
9.	28.27	63.617	477.12	29.	91.10	660.521	4953.90
9.5	29.84	70.882	531.61	30.	94.24	706.860	5301.45
10.	31.41	78.540	589.05	31.	97.38	754.769	5660.76
10.5	32.98	86.590	649.42	32.	100.53	804.250	6031.87
11.	34.55	95.033	712.74	33.	103.67	855.301	6414.75
11.5	36.12	103.869	779.01	34.	106.81	907.922	6809.41
12.	37.69	113.098	848.23	35.	109.95	962.115	7215.86
12.5	39.27	122.719	920.38	36.	113.09	1017.878	7634.08
13.	40.84	132.733	995.49	37.	116.23	1075.213	8064.09
13.5	42.41	143.139	1073.53	38.	119.38	1134.118	8505.88
14.	43.98	153.938	1154.53	39.	122.52	1194.593	8959.44
14.5	45.55	165.130	1238.47	40.	125.66	1256.640	9424.80
15.	47.12	176.715	1325.36	41.	128.80	1320.260	9901.95
15.5	48.69	188.692	1415.19	42.	131.94	1385.450	10390.87
16.	50.26	201.062	1507.96	43.	135.08	1452.200	10891.50
16.5	51.83	213.825	1603.68	44.	138.23	1520.530	11403.97
17.	53.40	226.981	1702.35	45.	141.37	1590.43	11928.22
17.5	54.97	240.529	1803.96	46.	144.51	1661.91	12464.32
18.	56.54	254.470	1908.52	47.	147.65	1734.95	13012.12
18.5	58.11	268.803	2016.02	48.	150.79	1809.56	13571.70
19.	59.69	283.529	2126.46	49.	153.93	1885.75	14143.12
19.5	61.26	298.648	2239.86	50.	157.08	1963.50	14726.25
20.	62.83	314.160	2356.20	51.	160.22	2042.83	15321.22

For tanks, cisterns, or reservoirs that have tapering sides, measure the sides or diameter, as the case may be, at a point four-tenths from the large end.

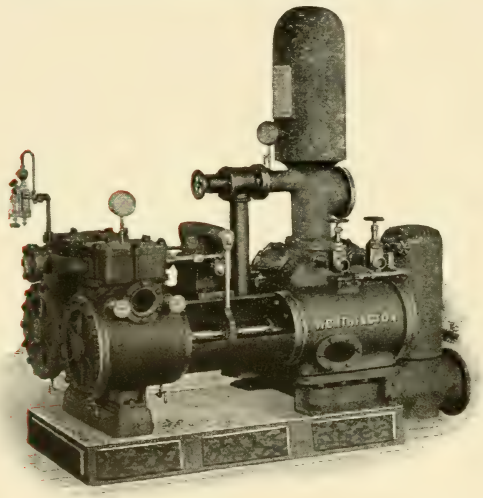
To compare the areas of round tanks or cisterns with square ones: To find the side of a square of equal area, multiply the diameter by .8862, or the circumference by .282.

A gallon of water (United States standard) weighs 8⅓ pounds, and contains 231 cubic inches.

A cubic foot of water weighs 62½ pounds, and contains 1,728 cubic inches, or 7½ gallons.

Mill Fire Protection, Continued.

Worthington "Underwriter" Pumps.



Underwriter Fire Pump.

(Size, 18x10x12, 1000 gals. per min.)

The Underwriter Fire Pump is the name adopted by the Associated Factory Mutual Insurance Companies to designate a duplex steam fire pump built in strict accordance with specifications issued by them, and copied in general design after the original Worthington Fire Pump.

The main points of difference between the "Trade Pump" and the "Underwriter" are:

Brass plungers instead of cast-iron plungers.

Bronze piston-rods and valve-rods instead of iron or steel.

Pump has brass-lined stuffing boxes instead of cast-iron.

Area of water-valves is 25 to 50 per cent. greater.

Steam and exhaust passages 20 to 50 per cent. greater.

Suction pipe connections two to four inches greater diameter.

Cushion valves better arranged.

Mill Fire Protection, Continued.

"Underwriter" Pumps, Concluded.

Air chamber is made much larger.

Shells and bolting are warranted especially strong.

The following necessary fittings, heretofore charged for as extras, are included in the price, and regularly furnished as a part of this pump, viz.:

A capacity plate is added.

A stroke gauge is added.

A vacuum chamber is added.

Two best quality pressure gauges.

A water-relief valve of large capacity.

A cast-iron relief valve discharge cone.

A set of brass priming pipes and special valves.

From two to four Chapman hose valves.

A sight feed cylinder lubricator.

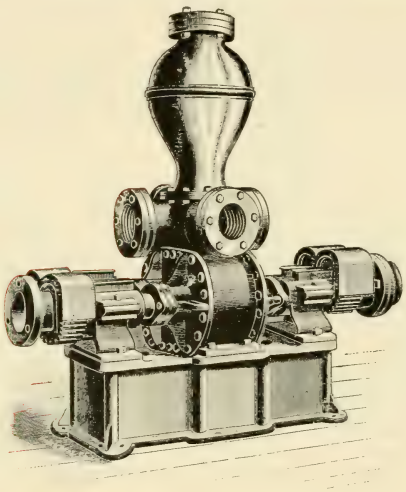
This pump, while ordinarily expected to exert a pressure of only 100 pounds to the square inch, is subjected to a pressure of 300 pounds, and rigidly tested in other ways. Air and vacuum chambers of large capacity are provided, and, in addition to the necessary number of hose valves, a large delivery opening enables a line of piping to be run to hydrants at a distance, or permits direct connection with the supply pipe of the sprinkler system.

"Underwriters" Pump Data.

Underwriters Rating: In gallons per minute.	Number of 1⅛ inch Smooth Nozzle Fire Streams.	Diameter of Steam Cylinders.	Diameter of Water Plungers.	Length of Stroke.	Sizes of Pipes for Short Lengths. To be increased as length increases.				Boiler Horse Power Required.
					Steam Pipe.	Exhaust Pipe.	Suction Pipe.	Discharge Pipe.	
500	2	14	7¼	12	3	4	8	6	100
750	3	16	9	12	3½	4	10	7	125
1000	4	18	10	12	4	5	12	8	180
1500	6	20	12	15	5	6	14	10	200

Mill Fire Protection, Continued.

S. Morgan Smith Rotary Fire Pumps.



The shafts are connected at both ends of the pump by machine cut spur gears protected by covers. The shafts are large and run in babbitted bearings of unusual length. All parts are fitted up with the greatest precision, the cams being ground in oil.

When pumps are used only at long intervals, they should be freed from water when stopped, for which purpose a drip plug is attached to the inlet. Oil should then be applied to the cams through the priming plug, after which the machine should be turned a few times, distributing the oil over the cams and effectually preventing rust and always insuring a nice working pump.

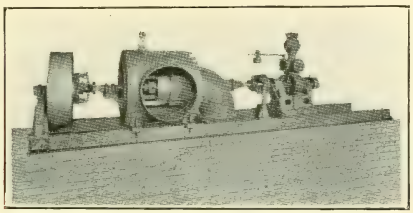
The pump should run so that the tops of the gears turn towards each other. Provision is made so that it can be driven from either end.

The suction is regularly fitted for wrought iron pipe connections, but can be fitted for cast iron or hose.

Mill Fire Protection, Continued.

Rotary Fire Pumps, Continued.

Each pump has five discharge openings. One is provided with a 2½-inch hose coupling and cap. One is threaded for wrought iron pipe of size stated in table on following page. The other outlets are provided with blank flanges, unless otherwise ordered. All pumps should be provided with automatic relief valves



A 21-inch wheel on horizontal shaft connected with fire pump, and pulley to drive dynamo, by Worrall Friction Clutches. Wheel is attached to the side of a penstock containing a pair of horizontal 30-inch McCormick Turbines, 300 horse power driving the mill.

In many instances, notably large plants, a separate wheel is put in arranged to drive the dynamo either by direct connection or with belts on one end of the wheel shaft, and the other end is extended to drive the water wheel with clutches in each case.

Such an auxiliary wheel with pump and pulley to drive dynamo is shown in above cut. On page 437 is shown a couple of vertical water wheels with a fire pump connected to the horizontal jack shaft by means of friction gears provided with V-shaped grooves accurately fitted to work together.

These pumps are mounted on very heavy cast iron bases, thus insuring perfect alignment.

Mill Fire Protection, Continued.

Rotary Fire Pumps, Concluded.

Table of Dimensions and Technical Data.

Size of Pump.	Standard Speed. Rev. per min.	Capacity in gallons. At standard speed.	Capacity in gallons. At one revolution.	Number of fire streams.	Dimensions in inches. Size of base.	Dimensions in inches. Height over all.	Dimensions in inches. Bottom of base to center of shaft.	Sizes of pipes in inches. Suction.	Sizes of pipes in inches. Discharge.	Number of points in friction gears, if driven by friction	Horse power to drive.
No. 4	350	580	1¾	2	31½ x 17¼	44	14⅝	5	4	10	45
" 5	300	750	2	3	34¾ x 19	46½	15⅞	6	5	12	60
" 6	250	1000	4	4	38¼ x 20½	62⅝	20	8	6	14	75

Note.—Small gear should not be less than 22 inches in diameter.

Remarks.—As a general rule water wheel power plants for cotton mills include rotary fire pumps. The insurance requirements are that these pumps are not to be belted, but are either to be driven with clutch couplings or with friction gears. In designing a water wheel outfit, therefore, this item should be taken into consideration in the beginning, and can generally be very simply disposed of.

Mill Fire Protection, Continued.

Hydrant Systems and Hose House Equipments.

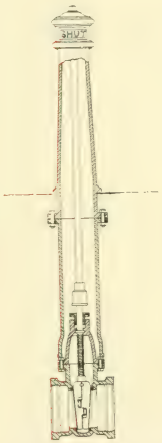
This consists of hydrants, post indicators on the gate valves, cast iron water pipe properly leaded together, the whole installed according to "insurance" requirements.

For sample plot showing a Hydrant System, see chapter on Mill Engineering.

Wherever it may be necessary to lay cast iron water mains with caulked joints in newly filled or made ground, or where there is any liability of water uncovering or exposing it, special preparation should be made to protect against damage—

(1). From settling in made ground which will open the lead joints or break off the pipes.

(2) Washing out or off of earth by water and the possibility of freezing under such conditions.

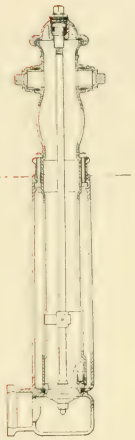


Post Indicators.

These should be placed on all outside gate valves, so as to show at all times whether the valves are open or shut. The accompanying cuts showing the post indicator, the gate valve itself, and the sectional diagram of both in use, will make clear their construction and operation.

Mill Fire Protection, Continued.

Hydrant System, Continued.



Hydrants.

These should be selected, if possible, with some idea of repairing valves without digging up.

Where set in clay or close soil, broken stone or other artificial drainage should be provided and proper foundation and packing of stone should be placed around the post to prevent blowing off the joint if the drainage washes away the retaining earth.

The outlets should be fitted with hose threads to interchange with those from which hose and assistance may be obtained—say, the nearest town.

All the wrench heads should be alike, so one wrench will open every hydrant on the premises, and in this feature they should interchange with the implements of the nearest assistance, either fire department or other mills.

The inlet and the post should have an area in excess of all theoretical demands.

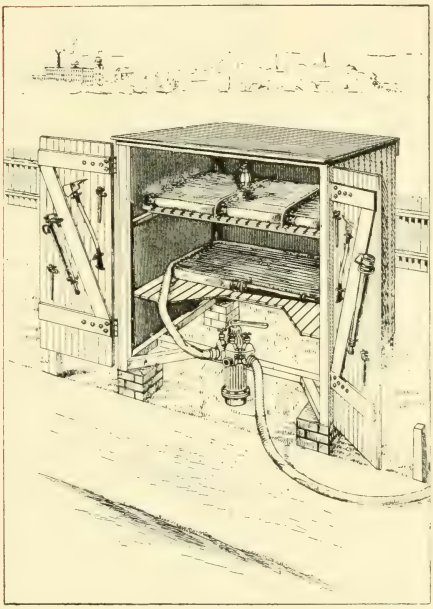
Special attention is called to the practice of some in making three-way hydrants with 5½-inch valves. Except in rare cases hydrants should never be fed by less than a 6-inch pipe, and should have valve inlet full size of main leading to it.

The independent gate hydrant is not desirable. The small valves are liable to be broken and the stems twisted off, to which is the additional objection on the part of some that the place for attaching the key is concealed and might cause delay, if not render the hydrant absolutely useless in the dark. The ordinary hydrant, with hose valves on each outlet, is recommended in preference to the independent gate pattern. Where the hydrant system connects with "city" mains, a steamer nozzle may be substituted for one of the outlets, as shown in the above cut.

The sectional diagram on the left shows the construction of a hydrant, both above and below ground.

Mill Fire Protection, Continued.

Hydrant System, Continued.



Interior View of House for Two or Three Way Hydrant, Fully Equipped.

Such an equipment for an ordinary mill represents a large outlay of money, all of which may be rendered useless if the hose and implements (which form but a small portion of the whole cost) are kept in towers and buildings where they are liable to be made inaccessible by fire and smoke.

The Standard Hose House provides an accessible place where all such implements may be assembled and kept ready or instant use.

This method avoids delay by having everything at hand, in addition to which the life of the only perishable part of

Mill Fire Protection, Continued.

Hydrant System, Concluded.

the equipment, viz., the fire hose, is prolonged by keeping it as shown—on slatted shelves in well-ventilated houses.

One hundred feet of hose attached to hydrant and coiled on lower shelf as shown, with standard play pipe attached.

Three lengths (or 150 feet) of extra hose arranged on upper shelf, divided by partition as shown.

Two axes, two bars, four spanners, two extra pipes, one lantern, all arranged as shown.

Ladder straps and coils of one-half inch hemp rope to suit height of buildings should be hung in each house.

Wrench always on hydrant.

A liberal supply of rubber hose-washers to be provided and hung in a conspicuous place.

Hose to be attached and coiled as shown in cut. If coiled as shown it will come off the shelf perfectly straight.

Extra hose to be coiled on upper shelf, as shown in cut, with male end of coupling in front, each length separated from the others by partitions six inches high, so that pulling out of one length will not foul and tangle with others.

The best and most durable fire hose for mill yard is known as Underwriters' Standard Cotton Rubber-Lined, actual size 2⅝″ diameter. The requirements are briefly as follows:

Fabric to be capable of standing bursting pressure of 400 pounds per square inch when new.

To have 2⅝″ waterways.

Rubber lining to be especially smooth and best quality.

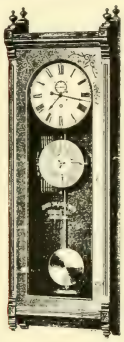
Couplings.—Must be the same size, pattern, and interchangeable with the public service or nearest mill from which assistance may be obtained.

Note.—In order to control each hose stream independently, gate valves may be attached to each outlet on hydrant as shown in cut, thus obtaining the very desirable feature of the independent Gate Hydrant at much less expense.

Mill Fire Protection, Continued.

"Eco" Time Detectors.

(Watchman's Clock.)



The Watchman's Recorder, either alone or in combination with an office Regulator (clock), is placed in the office, and stations located at such points throughout the building or premises as may be required for the watchman to visit.

The stations are connected with the Recorder by wires, and the rounds of the watchman are accurately recorded, each station in a separate space provided on the paper dial. Any number of watchmen can record at the same time and on the same dial, and each man's record be independent of the other.

The Recorder is an electric clock operated by magneto generators instead of by a chemical battery.

Each station the watchman visits is a magneto generator similar to that used in the telephone call.

The watchman carries a crank which he inserts in the station and by one turn, or part of a turn, generates sufficient electricity to make the record at the clock.

There is no chemical battery to run down or to be renewed.

It cannot be tampered with by the watchman and false records made upon it.

(Dimensions.)

Recorder only.—18 inches high, 14 inches wide.

Recorder with No. 1 Office Regulator.—70 inches high, 23 inches wide, sixty beats per minute, 14 inch dial, eight-day clock.

Recorder with No. 2 Office Regulator.—50 inches high, 20 inches wide, eighty beats per minute, 12 inch dial, eight-day clock.

Station Generators.—6 inches high, 4½ inches wide.

Mill Fire Protection, Continued.

Private Fire Department.

Every mill should have a proportionate number of its men drilled in the use of fire apparatus, more particularly the hose. This not only increases the efficiency of protection, but avoids the liability of accident and the maiming of inexperienced men in holding fire streams under high pressure. They should be regularly drilled to become expert in the handling of hose under actual fire pressure. The organization should be as follows:

Chief.—The active resident manager or superintendent; one who is ordinarily in high authority on the premises.

Assistant.—Master mechanic or some one ordinarily in constant attendance at the property and high in authority in the administration of the men.

Mill Fire Protection, Continued.

Private Fire Department, Continued.

Two or more companies should be formed as follows:

Captain.—For this position a reliable mechanic should be selected, preferably, the superintendent of a department of the works.

Hydrant Men.—Two men should be selected for this service whose special duty should be to attend to turning on and off the water, and connecting and disconnecting the hose at the hydrant; one man should be left at the hydrant; the other could assist in adding or taking out hose, replacing for breaks, etc.

Pipe Men.—For each company there should be three sets of pipe men, composed of three men each; these men should be heavy and strong and practiced in holding play-pipes; two men, ordinarily under average pressure can hold a stream, but when hose is taken up ladders, used on roofs, in buildings or under high pressure on the ground, three men are not too many to properly hold, move and direct a fire stream.

Extra Hose Men.—For each company there should be three extra hose men to assist in drawing the hose carts and laying the lines. The total strength of a company need not exceed twelve men, and where only *two-way hydrants* are in use two sets of pipe men would be sufficient, making the company consist of nine men in all.

An organization consisting of several companies, composed of a small number of men in each, makes it possible for the chief to direct through the captains the application of fire streams with the least confusion to the whole force, especially under excitement during a fire.

When the force consists of more than five companies, it should be divided into battalions of three companies each, and each battalion should have a chief, who should be selected for his coolness and general knowledge of the property.

Ladder Companies.—In a mill yard, where there are high

Mill Fire Protection, Continued.

Private Fire Department, Continued.

buildings, ladder companies, independent entirely of the hose companies, should be organized, composed of a captain and six men to each company. Permanent ladders can often be placed at small expense, where they would greatly facilitate the work of firemen.

Fire Practice.—Practice should be observed during favorable weather at least every two weeks.

This practice should consist of laying lines of hose and carrying them onto and into different buildings (without turning on water), in order that the men may become accustomed to handling the hose and making the connections with the couplings with rapidity, at the same time avoiding confusion.

It is well to select for each trial a different building, assuming the one selected or the adjoining one to be on fire: then have the chief engineer direct where the ladders should be placed and where streams should be carried, and, where practicable, water should be turned into hose that is carried up ladders and onto roofs, in order that the firemen may become accustomed to the "recoil" and weight to be managed.

To protect the men from accidents on ladders, ladder straps should be attached to all hose carried onto buildings, to take the weight and recoil on the ladder and off from the men.

A stream should never be manned on a roof with less than three men and they should be reinforced by two extras to pass signals and to assist in case the hose becomes unmanageable.

During fire practice, special attention should be given to the laying of hose without twists or kinks, and it should be especially understood that there should be no short turns anywhere in the length of hose, and that the play-pipes shall be so held as to make a gradual curve from the ground up.

This is an important feature in handling hose for the reason that—

1. Kinks or twists are liable to pull the hose away from the pipemen when water is turned on.
2. If there are any short bends near the play-pipes it

Mill Fire Protection, Continued.

Private Fire Department, Continued.

makes it almost impossible to hold the pipe, when, if it is under easy curve, the recoil is reduced to the minimum.

3. The hose is liable to burst by opening up a kink or short turn when the water is turned on, or to burst if a kink or short turn is taken in it while water is turned on.

Engineer's Force.—In addition to the foregoing organization there should be an engineer in charge of the pumps and boilers to see that steam is kept up, and that the pumps are operated in accordance with the demands made upon them, that is, not to run the pumps faster than necessary, and when they are driven to maximum speed to see that they are managed without danger of breakage.

Arrangements should also be made that extra men to fire the boilers should report to the engineer, as the consumption of steam by fire pumps requires steady firing, generally too much for the ordinary force of firemen at boilers

Where rotary pumps furnish water supply for fire protection, one or more men should be detailed to operate the gearing, start the pumps and keep them well oiled and give them such other care and attention while running as will prevent accident from over-speed or heating of the boxes.

Where the ordinary heavy grease is not at hand for prolonged use of rotary pumps, they may be kept cool by pouring on water.

In all cases, either on steam or rotary pumps, pressure should be gauged to suit the height of buildings and relief valves set accordingly. One hundred pounds pressure at pumps is in most cases the maximum pressure necessary; if a greater pressure than 100 pounds is attempted, first-class fire hose, specially selected to stand a higher pressure, should be provided.

Fire Alarm System.—The noise of machinery within buildings sometimes prevents the distinct hearing of whistle or bell alarm; for this reason it is best to have one signal for *Fire* or *General Alarm* which will call the men out of the building, and when they are out where they can hear distinctly, and while they are on their way to the stations or hose carriages, the signal can be blown or rung, designating the exact location of the fire.

Mill Fire Protection, Concluded.

Private Fire Department, Concluded.

In General.

The following is necessary for a complete equipment of a mill fire department in proportion to the demands of the property:

(1). Sufficient fire hose to concentrate the total capacity of the water supply upon any building or section of the property.

(2). A liberal supply of underwriters standard playpipes, so that the streams may be obtained without delay in gathering them during a fire.

(3). Spanners should be supplied in liberal numbers and distributed throughout the hose house equipment and on the hose carriages, and in many cases can be carried in the belt by the men.

(4). Fire axes and bars of standard size and pattern should be carried on all hose and ladder carts in liberal quantities.

(5). Ladder straps, for the purpose of fastening hose to the rounds of ladders and to window sills and other places where the weight of hose and the additional strain of the weight and recoil of water would otherwise make them unmanageable on ladders and buildings.

(6). Coils of one-half inch hemp rope with snap hooks should be provided for the ladder and hose companies, the length to be about two and one-half times the height of the highest building.

(7). Fire Lanterns. There should be a liberal supply of fire lanterns, of the pattern which will prevent the lamp being dropped through the bottom of the body, or extinguished by a stream of water striking it; the glass should also be guarded by a steel or wire fender.

(8). Provision should be made for hoisting hose, so that it can hang above ground vertically on supports to drain and dry in good shape This is best obtained by a frame hung over a mill tower, and as all hose is made in fifty feet lengths, the required height will be easily determined.

POWER PLANTS.

Under this heading we will consider in the following order:

Water Power,
Steam Power and
Electric Power.

These sub-divisions are arbitrarily taken, as the third one must of course overlap into one or the other of the preceding ones.

Steam Turbines are generally direct connected to generators and will therefore be described under the head of Electric Power Plants.

Water Power Plants.

Turbines have been greatly improved during the past ten years, both in efficiency and in the method of installation. A modern outfit does away with wooden supports and construction, substituting therefor structural **steel frame work, steel casings, and flumes.** Such an equipment properly designed and installed becomes almost indestructible, and maintains an astonishingly high point of efficiency almost indefinitely.

Steam Power Plants.

There is probably no subject in connection with a modern cotton mill that is receiving at the present time any more attention in the South than the Steam Plant. Until very recently the Southern manufacturer was content with any kind of an outfit that would furnish him power, and wanted that which would require the least amount of care and attention. His thought was directed entirely towards the manufacturing end of the business. As the margin of profit became smaller by increased competition, however, he was driven not only to bring down the cost in the manufacturing department, but to look into the other departments of his mill for possible economies. The department that has yielded the best results has probably been the Motive Power. Coal bills have been cut practically in half by throwing out old and obsolete plants and putting in the most modern and improved engines, boilers, and attendant apparatus and

Power Plants, Concluded.

accessories. These will be considered in their turn as follows:

Water and Fire Tubular Boilers,
Superheaters,
Fuel Economizers,
Fuel Oil Apparatus,
Mechanical Stokers,
Fuel Handling Rigs,
Mechanical Draft Apparatus,
Feed Water Heaters,
Feed Pumps,
Condenser,
Cooling Towers,
Simple and Compound Engines,
Electric Light and other Auxiliary Engines,
Modern Installations of Piping, embracing bent steel elbows, bent piping where necessary, high pressure steam gate valves, pipe covering, etc.,
Gravity Oiling System.

Electric Power Plants.

Electricity as a factor in the power plants of cotton mills has been developed entirely within the last ten years. The first plant of this kind was established at Columbia, S. C., to drive the duck mills of the Columbia Mills Company; and, strange to say, the general design and type of it has been but little modified up to the present time, although of course the details of the latest plants differ from it considerably. Electricity, therefore, as a drive for cotton mills can well be said to have been successful from the very beginning of its use.

In the subsequent chapter devoted to this subject, attention is called not only to the fitness of an **electric drive** for a new cotton mill, but also to its extraordinary adaptation to making additions and extensions to existing plants, whether mechanically or electrically driven.

The latest adaptation of electricity as a drive for cotton mills is in connection with steam turbines, or **turbo-generation,** as it is sometimes termed. The outlook for it is exceedingly promising, as will be seen from the discussion of the subject that is appended to the chapter on Electric Power Transmission.

WATER POWER PLANTS.

Typical Installations.

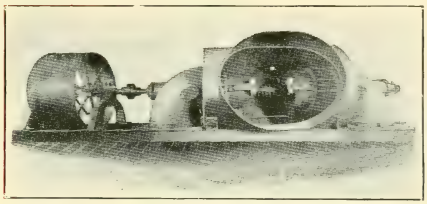


Figure 1.

Shows a pair of 51-inch McCormick Turbines, 1,300 horse power, with 10 foot diameter rope sheave, carrying 27 ropes 1½ inch diameter.

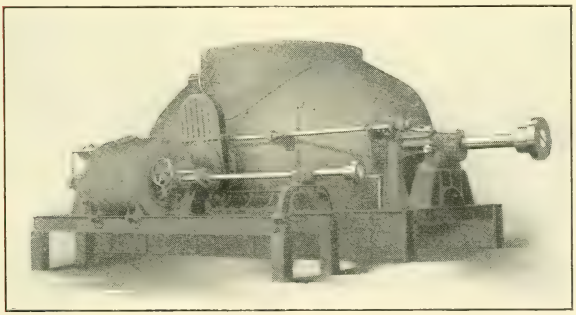
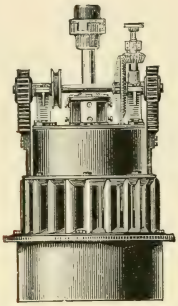


Figure 2.

Shows one of two sets of McCormick Turbines, operating under 85 feet head. Each one contains a pair of wheels developing 4,000 H. P., and a single wheel of 400 H. P.; the former direct connected to a three-phase generator and the latter to the exciter.

Note.—Those wishing to put in Turbines will describe their power and location, and should send a sketch of the same, no matter how crude. Much valuable time is often saved by sending a drawing or sketch, showing location for water wheels and machinery.

McCormick Turbines, Continued.



The tables of the **McCormick Wheel** are based on actual tests made in the Holyoke Testing Flume—the only reliable testing flume in the country. Both right and left hand wheels, of each size, have been tested and brought to over 80 per cent. efficiency. Although the tables are only based on 80 per cent. useful effect from the water used, all of the wheels have exceeded 80 per cent. in the tests, some of the larger sizes having run over 85 per cent. at less than full gate, with an average of more than 80 per cent. from half to full gate. (Gate opening here means the quantity of water—not the actual gate opening.)

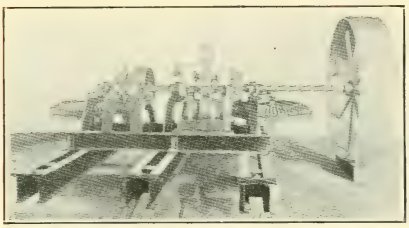
The wheels, when properly set, are guaranteed to develop the power and speed claimed for them.

When comparing these tables with those of other wheels, satisfy yourself that the tables of those wheels are reliably made. Many water wheel builders have tabled their wheels at 80 and even 90 per cent., when, if the truth were known, their wheels in actual tests would not exceed 60 to 70 per cent.

Water powers are becoming more valuable each year, and manufacturers can not afford to run wheels which sacrifice water and give but little power.

The wheel complete, as shown in the cut, includes a section of chain and balance weights for gates, delivered free on cars at the works. All wheels 30 inches and smaller will be shipped together, ready to set in flume. For convenience in handling, large size wheels will be shipped in sections with the smaller parts boxed.

McCormick Turbines, Continued.



Shows an outfit of machinery, including two vertical 51-inch Turbines, and a fire pump.

Directions for the Construction of Head and Tail Races.

The Head Race.

In constructing the canal or head race, a very frequent error is committed in failing to give it sufficient capacity. It should be wide and deep, and especially where the race is of considerable length, and a large quantity of water is to pass through it. As a general rule, the water should not flow faster than from 60 to 120 feet per minute. Where there is a long race, after the wheel has been running three or four hours the head frequently draws down from one to three feet. The effect of this is the same as if the dam had been lowered an equal distance—resulting in a loss of power which would have been prevented by making the race as wide and deep as it should be

When the water is to be conveyed to the turbines through iron pipes, the receiving ends of the pipes should be well submerged, so as to prevent any possibility of their drawing air. The velocity of the water through the pipes should not exceed three feet per second for short pipes, and as the length of the pipe increases the velocity should be reduced, until in pipes 200 to 250 feet in length, the velocity should not exceed two feet per second. It is, however, often necessary to run the water at a greater velocity than above named. See table giving the loss of head in different size pipes at different velocities.

McCormick Turbines, Continued.

The Tail Race.

This should be wide and deep, and the level of the bottom of the wheel pit should be carried from five to ten feet below the end of the forebay or flume, and if possible it should be carried out to the bed of the stream, as no tail race for even small wheels should have less than two feet of dead water in it before the wheels are put in motion, and where large wheels (using a great deal of water) are to be used, the tail race should have three or four feet of dead water in its entire length. By having tail race thus constructed, as soon as the water is discharged from the wheel or wheels, it will push out or displace the dead water in the race, thus preventing a loss of head. For instance, to be more plain, suppose the bottom of tail race is on a level with the water in main stream into which tail race discharges, when wheels are started the water in tail race would rise in proportion to the width of race and quantity of water flowing therein, and reduce the working head in proportion; while if the race were as first above stated, the water from the wheels would displace the dead water without rising above the water in the main stream, thus utilizing the full amount of head. From one to three feet of working head is often lost for want of proper depth and width of tail race.

Wheel Pit.

Here is where mill-owners and millwrights, in putting in turbine wheels, are more liable to err than elsewhere. Whether under high or low heads, the pit should be deep and wide. There is no case where this is more important than where a large wheel is run under a low head; as under these circumstances no loss of head, however small, can be afforded. A pit of insufficient size causes the water to react upon the wheel; an additional loss of power is also caused by the fact that a portion of the head is consumed in forcing the water out of the pit when there is not sufficient outlet. As a rule, the depth of the pit should not be less than the diameter of the wheel for wheels under 20 inches in diameter. Larger wheels should have an opening under them at least one and a half times as great as their diameter.

Water has but 100 per cent. in it, and a wheel that takes

McCormick Turbines, Continued.

out from 80 to 85 of that per cent., leaves but little force in it. To expect that the water coming through our wheels will have power to wash the sand and gravel out of its own pit, is to expect what will not be realized. Hence in putting in wheels do not calculate upon the water in the wheel pit to do any work for you. If you find it forming and dashing in the pit, then rest assured that your pit is either too shallow or too narrow, or both.

Setting Wheels Above Tail Water.

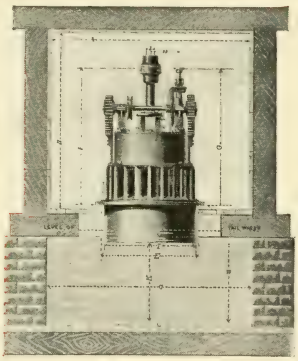
Sometimes in adapting wheels to high and even low heads, it becomes necessary to set the wheel some distance above the tail-water and conduct the water from the wheel through a Draft Tube. As good results may be obtained when the wheel is set in this manner as though it were placed at the bottom of the fall: provided this Draft Tube is perfectly air-tight, and its mouth submerged from 4 to 10 inches below the surface of tail water. As a rule we advise that the wheel be set at the bottom of the fall. In all cases when a Draft Tube is used, it should be made of iron, so as to secure durability and perfect tightness.

Directions for Setting Wheels.

In setting the "McCormick" Turbine in a wooden penstock, the first thing to do is to see that the floor of the flume is level: generally a ring made of soft wood is placed on the floor around the hole, on which the draft tube flange of the wheel, which is faced off, is set. It is very important that the flume be built on good foundations so as not to settle when the water is let in; a very good plan, and especially where large wheels are to be set, is to put four posts or iron columns under the timbers around the hole in the floor through which the draft tube passes.

The step and all bearings of the wheels are carefully adjusted before leaving the shops. Large wheels are, however, shipped in sections, and while it is not likely, yet it is possible for the traming screws in the step to be moved, so as to require readjustment. This should be looked after as the wheel is being put together in the flume. The draft

McCormick Turbines, Continued.



(See table on following page.)

tube is always first set in position, then the runner, or wheel proper, is placed on the step: afterwards comes the guide rim, and so on until all parts are together.

When the step is properly adjusted, there should be a space between the top of band on runner and bottom of inner edge of guide rim of one thirty-second of an inch. Care should also be taken lest the follower blocks in packing-box are not drawn too tightly around the wheel shaft. When the wheels are not to be run for some time, the step and step-shoe should be well covered with tallow to prevent rusting. In order that gates may work easily, all wheels over 24 inches are provided with chain and weights to counterbalance the weight of the gate. These weights can be used either inside or outside the penstock. When possible it is best to have them on the outside.

McCormick Turbines, Continued.

Dimensions of Turbine and Penstock.

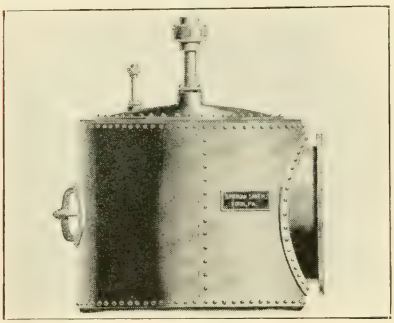
(In feet and inches.)

(Lettered columns correspond with letters in cut on preceding page.)

Diameter of Wheel.	A	B	C	D	E	F	I	J	K
9	2 3	2 9	2 9	1 6	1 4	1 10	1 2 3/4	1 5/8	1 3
12	3 0	4 0	3 9	1 10	1 8	2 11	1 6 3/4	2 1/8	1 6
15	4 0	4 6	5 0	2 4	2 1	3 5	1 11 1/8	2 3/8	2 0
18	4 6	4 10	5 9	2 11	2 4	3 8	2 2 3/8	2 7/8	2 6
21	5 3	5 6	6 6	3 3	2 9	4 2	2 6 3/4	3 1/8	2 9
24	6 0	5 9	7 3	3 6	3 1	4 7	2 10 7/8	3 3/8	3 0
27	7 0	6 0	8 0	3 9	3 6	4 9	3 2 1/2	3 5/8	3 3
30	7 6	6 6	9 0	4 0	3 10	5 3	3 7 5/8	3 7/8	3 6
33	8 6	7 6	10 0	4 3	4 3	6 1	4 0 1/4	4 1/8	3 9
36	9 0	8 0	11 0	4 6	4 6	6 6	4 4	4 5/8	4 0
39	10 0	8 6	12 0	4 9	4 11	6 10	4 8 5/8	5 1/8	4 3
42	10 6	8 9	13 0	5 3	5 4	7 1	5 1 3/8	5 3/8	4 6
45	11 6	9 0	14 0	5 9	5 8	7 6	5 5 3/8	5 7/8	5 0
48	12 0	9 6	15 0	6 0	6 0	8 0	5 9 1/4	6 3/8	5 3
51	12 9	10 6	16 0	6 3	6 4	8 9	6 1 1/4	6 7/8	5 6
54	13 6	11 3	17 0	6 6	6 9	9 3	6 6	7 3/8	5 9
57	14 0	11 6	18 0	7 0	7 1	9 6	6 10 1/8	7 7/8	6 3
60	15 0	12 0	19 0	8 0	7 5	9 10	7 1 7/8	7 3/8	7 0
66	16 0	12 6	20 0	9 0	8 0	10 1	7 6	7 7/8	7 6

McCormick Turbines, Continued.

Iron Flumes and Casings for Water Wheels.



The price of iron flumes usually exceeds the cost of building wooden ones, but for many locations, iron flumes are preferable on account of their durability and freedom from leakage.

The above cut represents iron flume as used for wheels of all sizes, excepting that the cast iron flange on inlet is only used on flumes for wheels 21 inches and smaller. Flumes for larger size wheels have wrought iron inlets with ends punched for connecting additional pipe.

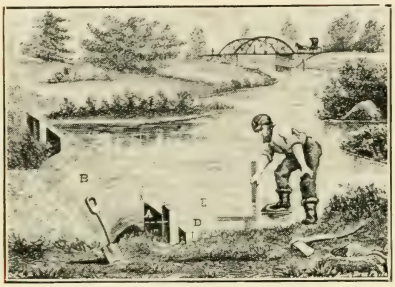
Each flume has heavy cast iron top and bottom and steel sides, and is provided with a movable lid and packing boxes for wheel and gate shafts. A large size man door is attached so that access can be had to the wheel on inside of flume.

McCormick Turbines, Continued.

Dimensions of Iron Flumes.

Size of Wheel.	Inside diameter of Flume in inches.	Diameter of Inlet Pipe.	Distance from Face of Inlet to Center of Wheel Shaft.	Approximate Weight of Flume.	
9	36	24	24	1650	For heads not exceeding 25 feet.
12	42	30	27	2000	
15	48	36	30	2400	
18	54	42	33	2800	
21	60	48	36	3200	
24	72	54	44	4500	For heads not exceeding 40 feet.
27	84	60	50	5500	
30	90	66	54	6400	
33	96	72	56	7400	
36	102	78	59	8500	
39	108	84	62	10000	
42	114	90	65	12000	
45	120	94	68	13500	
48	126	96	71	15000	
51	132	100	74	16500	
54	144	104	80	18000	
57	156	108	86	21000	
60	168	114	92	25000	
66	180	120	98	29000	
72	200	144	108	36000	

McCormick Turbines, Continued.



Rule for Measuring Water by Weirs.

For small streams where it is very important to know what quantity of water can be relied on, there is no better method of ascertaining this than by weir measurement.

A is a board extending across stream with notch B, over which water flows, beveled on down stream side. The stake at which measurements are taken is located 4 to 8 feet from weir, on up stream side, top being on a level with top notch in weir board as per line D. When the full flow of stream is passing over weir the depth will be the distance from line D to line E (obtained by measuring on stake). The level of water surface on down stream side of weir should not be less than 8 inches below bottom of notch B in the weir board. The length of the notch B should never be less than three to four times the depth for very small streams, and longer for larger streams. See table for weir measurements on next page.

Measurements of Large Streams.

In streams too large to measure by weir, the quantity of water is usually determined by "float measurement." In the use of this method it is important that the float be so made that it sinks well into the water. The measurements should be taken at a point where the velocity is not too great, and where the bed of stream is uniform. If the stream be wide, the velocity in feet per minute should be taken near the shore and in the centre ; the average then is the velocity of the stream.

To ascertain the cubic feet of water, multiply the depth by the width, multiply this product by the velocity in feet per minute, and the result will be the number of cubic feet flowing per minute, from which deduct 20 per cent. for losses by friction, etc.

McCormick Turbines, Continued.

Table Showing the Quantity of Water Passing Over Weirs in Cubic Feet per Minute.

Depth of water on weir in inches.	Cubic feet per minute passed for each foot of length of weir.	Depth of water on weir in inches.	Cubic feet per minute passed for each foot of length of weir.	Depth of water on weir in inches.	Cubic feet per minute passed for each foot of length of weir.	Depth of water on weir in inches.	Cubic feet per minute passed for each foot of length of weir.
1	4.85	4 3/4	50.20	8 1/2	120.18	12 1/2	214.32
1 1/8	5.78	4 7/8	52.18	8 5/8	122.82	12 3/4	220.76
1 1/4	6.68	5	54.22	8 3/4	125.52	13	227.30
1 3/8	7.80	5 1/8	56.25	8 7/8	128.14	13 1/4	233.92
1 1/2	8.90	5 1/4	58.33	9	130.93	13 1/2	240.54
1 5/8	10.00	5 3/8	60.42	9 1/8	133.65	13 3/4	247.22
1 3/4	11.23	5 1/2	62.55	9 1/4	136.43	14	254.03
1 7/8	12.45	5 5/8	64.68	9 3/8	139.18	14 1/4	260.83
2	13.72	5 3/4	66.86	9 1/2	141.99	14 1/2	267.77
2 1/8	15.02	5 7/8	68.98	9 5/8	144.80	14 3/4	274.70
2 1/4	16.36	6	71.27	9 3/4	147.64	15	281.72
2 3/8	17.75	6 1/8	73.45	9 7/8	150.47	15 1/4	288.82
2 1/2	19.17	6 1/4	75.77	10	153.35	15 1/2	295.93
2 5/8	20.63	6 3/8	78.04	10 1/8	156.20	15 3/4	303.10
2 3/4	22.11	6 1/2	80.36	10 1/4	159 14	16	310.36
2 7/8	23.63	6 5/8	82.63	10 3/8	162.07	16 1/4	317.69
3	25.20	6 3/4	85.04	10 1/2	164.99	16 1/2	325.03
3 1/8	26.78	6 7/8	87.43	10 5/8	167.89	16 3/4	332.42
3 1/4	28.43	7	89.82	10 3/4	169.92	17	339.91
3 3/8	30.06	7 1/8	92.16	10 7/8	173.90	17 1/4	347.45
3 1/2	31.75	7 1/4	94.67	11	176.92	17 1/2	355.02
3 5/8	33.45	7 3/8	97.11	11 1/8	179.94	17 3/4	362.77
3 3/4	35.22	7 1/2	99.50	11 1/4	182.99	18	370.34
3 7/8	36.98	7 5/8	102.10	11 3/8	186.03	18 1/4	378.12
4	38.80	7 3/4	104.63	11 1/2	189.13	18 1/2	385.87
4 1/8	40.63	7 7/8	107.13	11 5/8	192.20	18 3/4	393.66
4 1/4	42.49	8	109.74	11 3/4	195.32	19	401.63
4 3/8	44.39	8 1/8	112.31	11 7/8	198.47	19 1/4	409.58
4 1/2	46.29	8 1/4	114.91	12	201.59	19 1/2	417.48
4 5/8	48.22	8 3/8	117.51	12 1/4	207.94	19 3/4	425.68

For explanation of above table and construction of Weirs see preceding page.

McCormick Turbines, Continued.

Loss of Head in One Hundred Feet Length of Pipe, Steel Flumes, Etc., at Different Velocities.

Diameter of Pipe. Inches.	Cubic feet per minute at one foot per second velocity.	Loss at 1 Foot per Second.	1½ Ft. per Second.	2 Feet per Second.	3 Feet per Second.	4 Feet per Second.	5 Feet per Second.	6 Feet per Second.	7 Feet per Second.
3	2.95	.186	.476	.700	1.507	2.600	3.937	5.598	7.472
6	11.75	.0855	.213	.324	.702	1.214	1.843	2.619	3.003
9	26.50	.0543	.1422	.2053	.4440	.7690	1.170	1.6650	2.4500
12	47.10	.040	.0983	.1480	.3206	.5500	.8437	1.1925	1.5925
15	73.50	.0295	.0754	.1170	.2430	.4240	.6500	.9190	1.2250
18	106	.0237	.0600	0900	.1944	.3400	.5208	.7425	.9975
21	144	.0193	.0492	.0729	.1607	.2800	.4286	.6043	.8150
24	188	.0166	.0413	.0625	.1350	.2350	.3641	.5175	.6891
27	238	.0139	.0341	.0533	.1175	.2044	.3125	.4460	.5990
30	294	.0123	.0310	.0470	.1013	.1760	.2725	.3870	.5230
36	424	.0096	.0243	.0367	.0787	.1383	.2135	.3038	.4073
42	577	.0075	.0189	.0286	.0630	.1114	.1571	.2443	.3280
48	752	.0062	.0158	.0240	.0529	.0925	.1438	.2042	.2756
54	954	.0052	.0133	.0202	.0449	.0778	.1198	.1700	.2300
60	1176	.0044	.0113	.0173	.0383	.0667	.1062	.1458	.1972
66	1425	.0039	.0100	.0153	.0338	.0591	.0909	.1309	.1755
72	1696	.0035	.0089	.0137	.0301	.0530	.0815	.1162	.1698
78	1991	.0031	.0079	.0122	.0263	.0476	.0731	.1038	.1382
84	2308	.0028	.0072	.0110	.0243	.0426	.0656	.0939	.1256
90	2650	.0025	.0063	.0098	.0218	.0382	.0590	.0840	.1139
96	3008	.0022	.0055	.0088	.0196	.0342	.0531	.0754	.1018
102	3406	.0021	.0046	.0083	.0183	.0334	.0511	.0731	.1000
108	3816	.0019	.0043	.0075	.0172	.0307	.0482	.0693	.0964
120	4704	.0018	.0040	.0070	.0160	.0285	.0446	.0643	.0876
132	5702	.0017	.0038	.0067	.0154	.0276	.0430	.0619	.0851
144	6784	.0015	.0032	.0060	.0131	.0241	.0374	0523	.0735

McCormick Turbines, Continued.

Water Power Data.

231 cubic inches in one U. S. gallon.
7.48 gallons to one cubic foot (say 7½).
8.34 lbs. to one gallon (say 8⅓).
62.38 lbs. to one cubic foot.
Every foot elevation is equal to .43 lbs., or approximately half pound pressure to the square inch.
43,560 sq. ft. in one acre.
1 acre 1 foot deep will supply one foot per second for 12 hours.
Add $\frac{1}{5}$ to number of acres for the number of days of 10 hours each one foot per second or 60 feet per minute will give.
A square mile of water shed will give to a pond about three acres of water per day for every day in the year.
Aperture for gate 1 foot square will discharge 5 feet per second, or 5 acres 1 foot deep, 12 hours.
To find number of acres being drawn from reservoir, multiply sq. ft. of open gate by 5 for 12 hours, by 10 for 24 hours, and that by square root of depth of water above the gate.
43,560 (feet in acre) x 62⅓ (approximate weight in 1 cu. ft.) equals pounds of water in one acre 1 foot deep.
2,715,240 minus $\frac{1}{5}$ equals 80 per cent. (actual efficiency) of weight of water, equals 2,172,192.
2,172,192 divided by 33,000 equals 65.824 equals H. P. in 1 acre water, falling 1 foot during 1 minute.
For 10 foot fall, therefore :—65 824 x 10 equals 658.24, H. P. of 1 acre of water falling 10 ft. in one minute: 658 24 divided by 600 (minutes in 10 hours) equals 1.097, H. P. of 1 acre of water falling 10 ft in 10 hours, etc.

The **following tables of horse power** for different sized wheels are, as already stated, based upon an efficiency of only 80%, which is frequently exceeded with the McCormick wheels. The calculated horse power of water wheels is figured by the following rule :

Rule.—Multiply the cubic foot per minute of water by 62⅓, which is the weight of one cubic foot of water : multiply the product by the head, which will give the foot pounds ; divide the product by 33.000, which gives the full theoretical horse power of the water : multiply this by 80 per cent., which is the average efficiency of good wheels.

McCormick Turbines, Continued.

Table of Horse Powers.

Head in Feet.	15-INCH WHEEL.			18-INCH WHEEL.			21-INCH WHEEL.		
	Revolutions per Minute.	Discharge, Cubic Feet per Minute.	Horse Power.	Revolutions per Minute.	Discharge, Cubic Feet per Minute.	Horse Power.	Revolutions per Minute.	Discharge, Cubic Feet per Minute.	Horse Power.
5	178	566	4	144	828	6	137	1172	8
6	195	620	5	158	908	8	150	1283	11
7	211	670	7	170	980	10	162	1386	14
8	225	716	8	182	1048	12	173	1482	17
9	239	760	10	193	1111	15	184	1572	21
10	252	801	12	203	1172	17	194	1657	25
11	264	840	14	213	1229	20	203	1738	28
12	276	877	15	223	1283	23	212	1815	32
13	287	913	17	232	1336	26	221	1889	37
14	298	947	20	241	1386	29	229	1960	41
15	308	981	22	249	1435	32	237	2029	46
16	319	1013	24	257	1482	35	245	2096	50
17	328	1044	26	265	1528	39	253	2160	55
18	338	1074	29	273	1572	42	260	2223	60
19	347	1104	31	280	1615	46	267	2284	65
20	356	1132	34	288	1657	50	274	2343	70
21	365	1160	36	295	1698	53	281	2401	76
22	374	1188	39	302	1738	57	287	2457	81
23	382	1214	42	309	1777	61	294	2513	87
24	390	1240	45	315	1815	65	300	2567	93
25	398	1266	47	322	1852	70	306	2620	99
26	406	1291	50	328	1889	74	312	2672	105
27	414	1316	53	334	1925	78	318	2722	111
28	421	1340	56	340	1960	82	324	2772	117
29	429	1364	59	346	1995	87	330	2821	123
30	436	1387	62	352	2029	92	336	2870	130
31	443	1410	66	358	2063	96	341	2917	136
32	451	1432	69	364	2096	101	347	2964	143
33	458	1455	72	370	2128	106	352	3010	150
34	464	1476	75	375	2160	111	357	3055	157
35	471	1498	79	381	2192	115	362	3100	163
36	478	1519	82	386	2223	120	368	3144	171
37	484	1540	86	391	2254	126	373	3187	178
38	491	1561	89	397	2284	131	378	3230	185
39	497	1581	93	402	2314	136	383	3272	192
40	504	1601	96	407	2343	141	387	3314	200

McCormick Turbines, Continued.

Table of Horse Powers, Continued.

Head in Feet.	24-INCH WHEEL.			27-INCH WHEEL.			30-INCH WHEEL.		
	Revolutions per Minute.	Discharge, Cubic Feet per Minute.	Horse Power.	Revolutions per Minute.	Discharge, Cubic Feet per Minute.	Horse Power.	Revolutions per Minute.	Discharge, Cubic Feet per Minute.	Horse Power.
5	113	1547	11	106	1960	14	93	2361	17
6	124	1695	15	116	2147	19	102	2586	23
7	134	1831	19	125	2319	24	110	2793	29
8	143	1957	23	134	2479	30	118	2986	36
9	152	2076	28	142	2629	35	125	3167	43
10	160	2188	33	149	2771	41	132	3338	50
11	168	2295	38	157	2906	48	138	3501	58
12	175	2397	43	164	3036	55	144	3657	66
13	182	2495	49	170	3160	62	150	3806	74
14	189	2589	54	177	3279	69	156	3950	83
15	196	2680	60	183	3394	76	161	4089	92
16	202	2768	66	189	3505	84	167	4223	102
17	208	2853	73	195	3613	92	172	4353	111
18	214	2936	79	200	3718	101	177	4479	121
19	220	3016	86	206	3820	109	182	4602	132
20	226	3095	93	211	3919	118	186	4721	142
21	232	3171	100	217	4016	127	191	4838	153
22	237	3246	107	222	4110	136	195	4952	164
23	242	3318	115	227	4203	146	200	5063	176
24	248	3390	122	231	4293	155	204	5172	187
25	253	3460	130	236	4382	165	208	5278	199
26	258	3528	138	241	4468	175	212	5383	211
27	263	3595	146	245	4554	185	216	5486	223
28	267	3661	154	250	4637	196	220	5586	236
29	272	3726	163	254	4719	206	224	5685	249
30	277	3790	171	259	4800	217	228	5782	262
31	281	3853	180	263	4879	228	232	5878	275
32	286	3914	189	267	4957	239	236	5972	288
33	290	3975	198	271	5034	251	239	6064	302
34	295	4035	207	275	5110	262	243	6156	316
35	299	4094	216	280	5184	274	246	6246	330
36	303	4152	225	283	5258	286	250	6334	344
37	307	4209	235	287	5331	298	253	6421	359
38	312	4265	244	291	5402	310	257	6508	373
39	316	4312	254	295	5473	322	260	6593	388
40	320	4376	264	299	5542	335	263	6677	403

McCormick Turbines, Continued.

Table of Horse Powers, Continued.

Head in Feet.	33-INCH WHEEL.			36-INCH WHEEL.			39-INCH WHEEL.		
	Revolutions per Minute.	Discharge, Cubic Feet Per Minute.	Horse Power.	Revolutions per Minute.	Discharge, Cubic Feet per Minute.	Horse Power.	Revolutions per Minute.	Discharge, Cubic Feet per Minute.	Horse Power.
5	81	2888	21	79	3316	25	69	3808	29
6	89	3163	28	87	3632	32	76	4270	38
7	96	3417	36	94	3923	41	82	4612	48
8	102	3653	44	100	4194	50	87	4930	59
9	109	3875	52	106	4449	60	93	5229	71
10	114	4084	61	112	4689	70	98	5512	83
11	120	4284	71	118	4918	81	103	5781	96
12	125	4474	81	123	5137	93	107	6038	109
13	131	4657	91	128	5347	105	111	6285	123
14	135	4833	102	133	5548	117	116	6522	138
15	140	5002	113	137	5743	130	120	6751	153
16	145	5166	124	142	5931	143	124	6972	168
17	149	5326	136	146	6114	157	127	7187	184
18	154	5480	149	150	6291	171	131	7395	201
19	158	5630	161	154	6464	185	135	7598	218
20	162	5777	174	158	6632	200	138	7795	235
21	166	5919	187	162	6795	215	142	7988	253
22	170	6058	201	166	6955	231	145	8176	271
23	174	6195	215	170	7112	247	148	8359	290
24	177	6328	229	174	7265	263	151	8539	309
25	181	6458	243	177	7414	280	155	8715	329
26	185	6586	258	181	7561	297	158	8888	349
27	188	6712	273	184	7705	314	161	9057	369
28	192	6835	288	187	7847	332	164	9223	390
29	195	6956	304	191	7985	349	166	9387	411
30	198	7075	320	194	8122	368	169	9547	432
31	202	7191	336	197	8256	386	172	9705	454
32	205	7307	353	200	8388	405	175	9860	476
33	208	7420	370	204	8518	424	178	10013	499
34	211	7531	386	207	8646	444	180	10164	522
35	214	7641	404	210	8773	464	183	10312	545
36	217	7750	421	213	8897	484	186	10459	568
37	220	7857	439	216	9020	504	188	10603	592
38	223	7962	457	218	9141	524	191	10745	617
39	226	8066	475	221	9260	545	193	10885	641
40	229	8169	493	224	9378	566	196	11024	666

McCormick Turbines, Continued.

Table of Horse Powers, Continued.

Head in Feet.	42-INCH WHEEL.			45-INCH WHEEL.			48-INCH WHEEL.		
	Revolutions per Minute.	Discharge. Cubic Feet per Minute.	Horse Power.	Revolutions per Minute.	Discharge. Cubic Feet per Minute.	Horse Power.	Revolutions per Minute	Discharge. Cubic Feet per Minute.	Horse Power.
5	67	4786	36	61	5096	38	55	5749	43
6	74	5242	47	67	5582	50	60	6298	57
7	80	5662	59	72	6030	63	65	6802	72
8	85	6053	73	77	6446	77	70	7272	87
9	90	6421	87	82	6837	93	74	7713	104
10	95	6768	102	87	7207	108	78	8130	122
11	100	7098	118	91	7558	125	82	8527	141
12	104	7414	134	95	7894	143	85	8906	161
13	108	7717	151	99	8217	161	89	9270	182
14	112	8008	169	102	8527	180	92	9620	203
15	116	8289	187	106	8826	200	95	9958	225
16	120	8561	207	109	9116	220	98	10284	248
17	124	8824	226	113	9396	241	101	10601	272
18	128	9080	247	116	9669	263	104	10908	296
19	131	9329	267	119	9934	285	107	11207	321
20	134	9571	289	122	10192	308	110	11498	347
21	138	9808	311	125	10443	331	113	11782	373
22	141	10038	333	128	10689	355	115	12059	400
23	144	10264	356	131	10929	379	118	12330	428
24	147	10485	380	134	11164	404	121	12595	456
25	150	10701	404	137	11395	430	123	12855	485
26	153	10913	428	139	11620	456	126	13110	515
27	156	11121	453	142	11842	483	128	13360	545
28	159	11325	479	145	12059	510	130	13605	575
29	162	11525	505	147	12272	537	133	13845	606
30	165	11722	531	150	12482	565	135	14082	638
31	167	11916	558	152	12689	594	137	14315	670
32	170	12107	585	155	12892	623	139	14544	703
33	173	12294	613	157	13091	652	141	14769	736
34	175	12479	641	160	13288	682	144	14992	770
35	178	12661	669	162	13482	713	146	15210	804
36	180	12841	698	164	13674	743	148	15426	839
37	183	13018	727	166	13862	775	150	15639	874
38	185	13193	757	169	14048	806	152	15849	910
39	188	13365	787	171	14232	838	154	16056	946
40	190	13536	818	173	14413	871	156	16261	982

McCormick Turbines, Continued.

Table of Horse Powers, Continued.

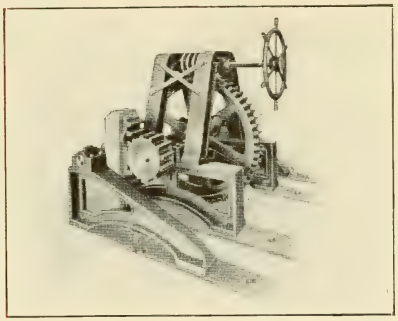
Head in Feet.	51-INCH WHEEL.			54-INCH WHEEL.			57-INCH WHEEL.		
	Revolutions per Minute.	Discharge, Cubic Feet per Minute.	Horse Power.	Revolutions per Minute.	Discharge, Cubic Feet per Minute.	Horse Power.	Revolutions per Minute.	Discharge, Cubic Feet per Minute.	Horse Power.
5	56	6545	49	51	7707	58	50	8646	65
6	61	7170	65	56	8449	76	55	9472	85
7	66	7745	81	60	9119	96	59	10231	108
8	70	8279	100	64	9748	171	63	10937	132
9	75	8782	119	68	10340	140	67	11601	157
10	79	9257	139	72	10899	164	70	12228	184
11	82	9708	161	76	11431	190	74	12825	213
12	86	10140	183	79	11939	216	77	13395	242
13	90	10554	207	82	12427	244	80	13942	273
14	93	10952	231	85	12896	272	83	14468	306
15	96	11337	257	88	13348	302	86	14976	339
16	99	11709	283	91	13786	333	89	15467	374
17	103	12069	310	94	14210	365	92	15943	409
18	106	12419	337	97	14622	397	94	16406	446
19	108	12759	366	99	15023	431	97	16855	483
20	111	13091	395	102	15413	465	100	17293	522
21	114	13414	425	105	15794	501	102	17720	562
22	117	13730	456	107	16166	537	104	18137	602
23	119	14038	487	109	16529	574	107	18545	644
24	122	14340	520	112	16885	612	109	18944	687
25	124	14636	552	114	17233	651	111	19334	730
26	127	14926	586	116	17574	690	113	19717	774
27	129	15210	620	119	17909	730	116	20093	819
28	132	15489	655	121	18237	771	118	20461	865
29	134	15763	690	123	18560	813	120	20824	912
30	136	16033	726	125	18878	855	122	21179	960
31	138	16298	763	127	19190	898	124	21530	1008
32	141	16559	800	129	19497	942	126	21874	1057
33	143	16815	838	131	19799	987	128	22213	1107
34	145	17068	876	133	20097	1032	130	22547	1158
35	147	17317	915	135	20390	1078	132	22876	1209
36	149	17563	955	137	20679	1124	134	23201	1262
37	151	17805	995	139	20965	1172	135	23521	1315
38	153	18044	1036	141	21246	1219	137	23837	1368
39	155	18280	1077	142	21524	1268	139	24148	1423
40	157	18513	1119	144	21798	1317	141	24456	1478

McCormick Turbines, Continued.

Table of Horse Powers, Concluded.

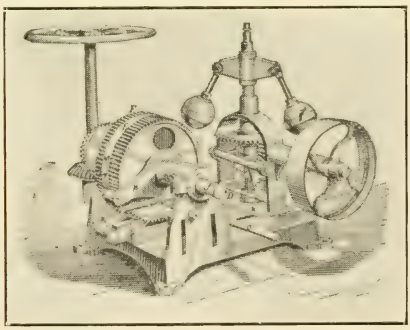
Head in Feet.	60-INCH WHEEL.			66-INCH WHEEL.			72-INCH WHEEL.		
	Revolutions per Minute.	Discharge. Cubic Feet per Minute	Horse Power.	Revolutions per Minute.	Discharge. Cubic Feet Per Minute.	Horse Power.	Revolutions per Minute.	Discharge. Cubic Feet per Minute.	Horse Power.
4	42	9723	58	38	11765	71	37	14796	89
5	46	10870	82	42	13154	99	41	16546	113
6	50	11908	108	46	14409	130	48	18119	164
7	54	12862	136	49	15564	164	49	19580	205
8	58	13740	165	53	16669	201	52	20931	252
9	62	14584	198	56	17648	240	56	22194	301
10	65	15374	232	59	18602	281	59	23412	354
11	68	16174	267	62	19510	324	61	24542	407
12	71	16842	305	65	20378	369	64	25627	464
13	74	17529	344	67	21210	416	67	26690	524
14	77	18210	384	70	22011	465	70	27687	586
15	79	18829	426	72	22783	516	72	28662	649
16	82	19447	470	75	23530	568	74	29614	716
17	85	20044	514	77	24255	623	77	30522	759
18	87	20625	561	79	24957	678	79	31408	854
19	89	21192	608	81	25641	736	81	32272	902
20	92	21741	657	83	26308	795	83	33114	1000
21	94	22279	706	86	26958	855	85	33911	1076
22	96	22803	758	88	27592	917	88	34709	1153
23	98	23316	810	89	28212	980	90	35484	1233
24	101	23817	863	91	28819	1045	91	36259	1314
25	103	24308	918	93	29413	1111	93	37012	1398
26	105	24789	973	95	29996	1178	94	37743	1482
27	107	25262	1030	97	30567	1247	96	38452	1568
28	109	25725	1087	99	31128	1317	99	39161	1656
29	111	26181	1147	100	31678	1388	100	39847	1748
30	112	26629	1207	102	32221	1460	102	40534	1821
31	114	27068	1268	104	32753	1534	104	41199	1929
32	116	27501	1329	106	33277	1609	105	41863	2024
33	118	27928	1392	107	33793	1685	107	42528	2120
34	120	28348	1456	109	34297	1762	108	43170	2217
35	121	28762	1521	110	34802	1869	110	43790	2318
36	123	29170	1586	112	35296	1920	112	44410	2415
37	125	29573	1653	113	35782	2000	113	45030	2517
38	127	29970	1720	115	36264	2082	114	45629	2620
39	128	30361	1789	117	36738	2164	116	46227	2726
40	130	30748	1858	118	37206	2248	117	46802	2828

McCormick Turbines, Continued.



Worm Gearing for Operating Bulk-Head Gates.

The above cut shows one of the many arrangements for operating the head gates in canals, mill races and other water ways.



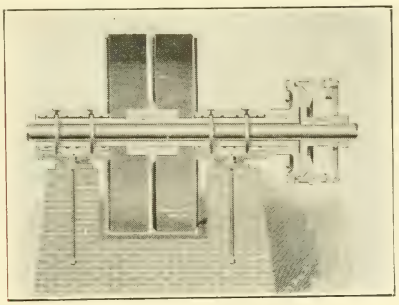
Water Wheel Governor.

The above cut represents one of the best water wheel governors made. It is made in two different styles to accommodate the machinery the Turbine is driving.

McCormick Turbines, Concluded.

Iron Trusses for Heavy Gears.

Iron trusses are the best for the support of heavy gearing. The cuts on page 435 show some of the many styles of trusses supported by girders.



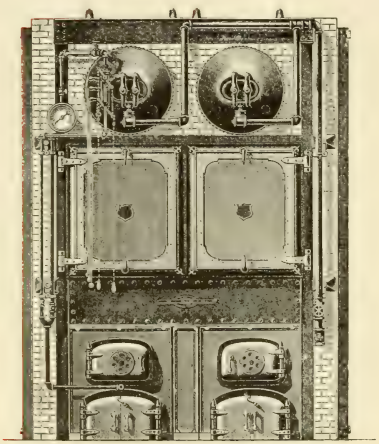
Friction Clutch and Quill Pulley.

The Worrall Friction Clutch automatically centers and adjusts itself. Will work exposed to frost, steam, acids and water. Each part of the Friction is keyed solid to shaft upon which it runs.

The above cut shows a Worrall Friction Clutch connecting the shaft with a Quill or Hollow shaft carrying pulley. The Quill is supported by independent bearings and is not dependent on the journals supporting the shaft which passes through the Quill.

Size of Clutch.	Horse Power at 100 Revolutions.	Space on Shaft for Coupling & Shipper.	Size of Clutch.	Horse Power at 100 Revolutions.	Space on Shaft for Coupling & Shipper.
6	2	7 inches.	24	75	24 inches.
8	2½	8 "	27	125	26 "
9	3	10 "	30	150	28 "
10	5	12 "	33	200	30 "
12	8	18 "	36	250	32 "
13½	12	18 "	42	385	34 "
15	18	20 "	45	560	42 "
18	30	22 "	54	735	48 "
21	50	24 "	60	1000	52 "

WATER TUBE BOILERS.



Babcock & Wilcox Horizontal Type.

The efficiency of a steam engine is often, but incorrectly, based on the amount of fuel burned per indicated horse power per hour; but it is more properly based on the steam consumption. The highest class of compound engines running condensing will use from 11½ to 16 pounds of steam per indicated horse-power per hour, which is fully fifty per cent. less than the average performance of an engine working non-condensing under steam pressures of 100 pounds or less. The fuel used per horse-power, therefore, depends on the quality of the coal and upon the efficiency of the boilers, as well as upon the efficiency of the engine. And not only that, but the boilers must be specially constructed for carrying high pressures. The objection to the use of fire tubular boilers for this work has always been that the safe working pressure allowed is cut down from year to year. This is not the case with properly constructed water tubular boilers, which in special cases carry as high as 500 pounds pressure in regular work. The usual pressures carried, however, for compound condensing engines run from 135 to 180 pounds. The question of "superheating" is also a vital one and will be treated under its own heading on a subsequent page.

B. & W. Boilers, Continued.

The advantages peculiar to the Babcock & Wilcox Boilers that fit it for use in cotton mills are as follows :

(1) **Thin Heating Surface in Furnace.**—The thick plates necessarily used in fire tubular boilers, in the furnace, or immediately exposed to the fire not only hinder the transmission of heat to the water, but admit of overheating, and even burning the side next the fire, with consequent strains, resulting in loss of strength, cracks, and tendency to rupture. This is admittedly the direct cause of many explosions. Water tubes, however, admit of thin envelopes for the water next the fire, with such ready transmission of heat that even the fiercest fire cannot overheat or injure the surface, so long as it is covered with water upon the other side.

(2) **Joints Removed from the Fire.**—Riveted joints, with their consequent double thickness of metal, in parts exposed to the fire, give rise to serious difficulties. Being the weakest parts of the structure, they concentrate upon themselves all strains of unequal expansion, giving rise to frequent leaks, and not rarely to actual rupture. The joints between tubes and tube sheets also give much trouble when exposed to the direct fire, as in locomotive and tubular boilers. These difficulties are wholly overcome by the use of lap-welded water-tubes, with their joints removed from the fire.

(3) **Large Draft Area.**—This, which is limited in fire-tubes to the actual area of the tubes, in this Boiler is the whole chamber, within which the tubes are enclosed, which, with down draft, give ample time in the passage of the heated gases to the chimney for thorough absorption of their heat.

(4) **Complete Combustion.**—The perfection of combustion depends upon a thorough mixture of the gases evolved from the burning of fuel with a proper quantity of atmospheric air : but this perfect mixture rarely occurs in ordinary furnaces, as is proved by chemical analysis, and also by the escape of smoke, upon the introduction of any smoke producing fuel. In this Boiler the currents of gases after leaving the furnace are broken up and thoroughly mingled by passing between the staggered tubes, and have an opportunity to complete their combustion in the triangular chamber between the tubes and drum.

(5) **Thorough Absorption of the Heat.**—There are important advantages gained in this respect in consequence of the course of the gases being more nearly at right angles to the heating surface, impinging thereon instead of gliding by in parallel lines, as in fire-tube boilers.

(6) **Efficient Circulation of Water.**—As all the water in the boiler tends to circulate in one direction, there are no in-

B. & W. Boilers, Continued.

terfering currents; the steam is carried quickly to the surface, all parts of the boiler are kept at a nearly equal temperature, preventing unequal strains, and by the rapid sweeping current the tendency to deposit sediment on the heating surface is materially lessened.

(7) **Dryness of Steam.**—The large disengaging surface of the water in the drum, together with the fact that the steam is delivered at one end and taken out at the other, secures a thorough separation of the steam from the water, even when the boiler is forced to its utmost. Most tubular, locomotive and sectional boilers make wet steam, "priming," or "foaming," as it is called.

(8) **Steadiness of Water Level.**—The large area of surface at the water line, and the ample passages for circulation, secure a steadiness of water level not surpassed by any boiler. This is a most important point in boiler construction and should always be considered when comparing the Horizontal and Vertical types of Water-Tube Boilers. Take, for instance, a Babcock & Wilcox Boiler of 250 horse-power and a well-known Vertical Water-Tube Boiler. The former lowers its water line at the rate of one inch in 5.87 minutes, and the latter at the rate of one inch in 1.15 minutes. Or, if we suppose the feed pumps to break down when the boilers are running at their rated capacity and the water line is at the normal height, it will be 1 hour and 23 minutes before the water is all out of the drum of the Babcock & Wilcox Boiler, while with the Vertical Boiler the crown sheet will be bare in 20.9 minutes.

(9) **Freedom of Expansion.**—The arrangement of the parts forming a flexible structure, allows any member to expand without straining any other, the expanded connections being also amply elastic to meet all necessities of this kind.

(10) **Safety from Explosions.**—The freedom from unequal expansion avoids the most frequent cause of explosions, while the division of the water into small masses prevents serious destructive effects in case of accidental rupture. The comparatively small diameter of the parts secures, even with thinness of surface, great excess of strength over any pressure which it is desirable to use. So powerful is the circulation of the water, that no part will be uncovered to the fire until the quantity of water in the boiler is so far reduced that if overheating should occur no explosion could result.

(11) **Capacity.**—This is a point of the greatest importance, and upon it depends, in a large measure, the satisfactory performance of any boiler in several particulars. Unless sufficient steam and water capacity is provided there will not be regularity of action: the steam pressure will suddenly rise, and as suddenly fall, and the water level will be subject to

B. & W. Boilers, Continued.

frequent and rapid changes; and, if the steam is drawn suddenly from the boiler, or the boiler crowded, wet steam will result.

Water capacity is of more importance than steam space, owing to the small relative weight of the steam. Twenty-three cubic feet of steam, or one foot of water space, are required to supply one horse-power for one minute, the pressure meantime falling from 80 pounds to 70 pounds per square inch. The value of large steam room is therefore generally much overrated; but, if it be too small, the steam in passing off will sweep the water with it in the form of spray. Too much water space makes slow steaming and waste of fuel in starting. Too much steam space adds to the radiating surface and increases the losses from that cause.

The cubical capacity of this Boiler, per horse-power, is equal to that of the best practice in tubular boilers of the ordinary construction. The fire surface being of the most effective character, these Boilers will, with good fuel and a reasonably economical engine, greatly exceed their rated power, though it is seldom economy to work a Boiler above its nominal power. The space occupied by this Boiler and setting is equal to about two-thirds that of the same power in fire tubular boilers.

(12) **Accessibility for Cleaning.**—This is of the greatest importance and is secured to the fullest extent Hand-holes, with metal joints opposite each end of each tube, permit access thereto for cleaning, and a manhole in the steam and water drum and hand-holes in mud drum are provided for the same purpose. All portions of both the exterior and interior surface are fully accessible for cleaning. The occasional use of steam through a blowing pipe attached to a rubber hose operated through doors in the side walls will keep the tubes free from soot and in condition to receive the heat to the best advantage.

(13) **Least Loss of Effect from Dust.**—The ordinary fire-tube or flue, receiving the dust from the fire on the interior is quickly covered from one-third to one-half its surface, and in time is completely filled. The water tube, however, will retain but a limited quantity on its upper side, after which it becomes, in a measure, self-cleaning.

(14) **Durability.**—Besides the important increase of durability due to the absence of deteriorating strains, and of thick plates and joints in the fire, there is no portion of the boiler exposed to the abrasive action which so rapidly destroys the ends of fire tubes, or to the blow-pipe action of the flame upon the crown sheet, bridge walls, and tube sheets, which are so destructive frequently to ordinary, particularly locomotive, boilers. Neither is there any portion of the surface

B. & W. Boilers, Continued.

above the water level exposed to the fire. For these reasons these Boilers are durable, and less liable to repairs than other Boilers under the same circumstances and having the same care.

(15) **Ease of Transportation.**—Being made in sections, which are readily put together with a simple expanding tool, these Boilers may be easily and cheaply transported where it would be impossible to place a Boiler of ordinary construction. They can be made in parts small enough for mule transportation, if required.

(16) **Repairs.**—As now constructed, these Boilers seldom require repairs; but, if from any cause, such should be necessary, any good mechanic can make them with the tools usually found in boiler shops. Should a tube require to be renewed it can be removed and a new one substituted, the same as in a tubular boiler.

(17) **Practical Experience.**—The above advantages would be worthy of attention if they were only theoretical, but they have been, in fact, demonstrated by the experience of twenty years, under a great variety of circumstances and of treatment. Of the total number sold, less than two per cent. have so far as is known been thrown out of use; while a large number of customers have repeated their orders—some a score of times.

Vertical Header Type.

(For pressures not exceeding 160 lbs.)

The following description will make clear the construction of this boiler and what is included in a specification:

The boiler is composed of sections made up of 4-inch wrought-iron tubes expanded into **Cast Headers**, and connected into a steam and water drum by 4-inch tubes expanded into upper ends of headers, and into wrought-steel cross boxes on under side of drum.

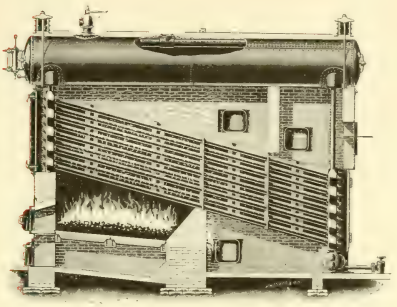
The mud drum, placed at the lowest point of the structure, is connected by 4-inch nipples to the bottom ends of the rear headers. The tube and nipple connections between all parts are made by expanded joints.

The boiler is suspended at front and rear from wrought-iron supporting frames, entirely independent of the setting, to allow for contraction and expansion without straining either the boiler or the brick-work, and to allow of repairs to, or renewal of, the latter without disturbing the boiler or its connections.

The cylindrical portion of the steam drum is made of Open Hearth steel plates, the longitudinal seams double riveted. The circular seams are lap-jointed, single-riveted. The outside edges of all plates are planed. All rivets are driven by hydraulic pressure and held until cool.

All drum heads are fitted with manholes, 11 x 15 inches.

B. & W. Boilers, Continued.



The heads are hydraulic forged at a single heat with manhole ring and stiffening plate in position, and have flat raised seats for stand pipe and feed connections. The edges of heads and manhole plates are turned off true.

The manhole plates and guards are of forged steel, the plate faced and machined to a true oval to fit the head.

The drum cross boxes are hydraulic forged from a single Open Hearth steel plate without seams or rivets.

Steam is taken from a dry pipe perforated on top side and connected into a flanged steam opening on top of drum. The steam flanges are of forged steel, faced true to receive companion flanges, and fitted with stud bolts.

When two or more steam drums are used on one boiler, the drums are connected by a cross pipe having a flanged outlet for main steam connection.

All drum plates are of best Open Hearth steel, stamped with maker's name, and having a tensile strength of from 56,000 to 62,000 pounds per square inch; with an elongation of not less than 25% in a parallel test piece of 8 inches, accompanied by a reduction in area of at least 50%, and will endure bending double before and after being brought to a flanging heat and quenched.

All forgings for pressure parts are made from Open Hearth steel of from 52,000 to 58,000 pounds tensile strength and are formed by hydraulic power.

The sections are built up of charcoal-iron tubes expanded into cast iron vertical headers of serpentine form, disposing the tubes in a staggered position when assembled in the furnace. An oval hand-hole, of sufficient size to permit the cleaning, removal and renewal of a tube, is placed opposite each tube end, this hand-hole having a raised seat milled off to a true surface.

The hand-holes are closed on the outside by a cap milled to a true surface which is held in position by a forged steel oval safety clamp entirely closing the hand-hole opening

B. & W. Boilers, Continued.

from the inside, secured by a ball-headed bolt to insure correct alignment with outside cap nut. The outside hand-hole joint is made tight, metal to metal, without packing of any kind.

The mud drum is 12 inches in diameter and of proper length to be connected with all of the sections in the boiler by means of wrought nipples expanded into counter-bored seats. It is tapped for blow-off connections on its rear side, and furnished with hand-holes for cleaning. The hand-hole plates and guards are of forged steel. The hand-hole plates are faced, and are held in place by hand-hole bolts and nuts.

The mud drums are of the best car-wheel mixture charcoal cold-blast iron, and are tested to 300 pounds pressure.

The front is of ornamented design, consisting of a heavy wrought-iron "I" and channel beam frame fitted with large doors for access to the hand-hole plates and front headers.

The fire fronts have independent frames for fire doors which are bolted on, and ash doors are fitted with blast catches. All joints fitted and faces of doors planed.

Wrought-iron doors in heavy frame are provided for access to back headers. Cast-iron side cleaning doors are provided for access to the tube surfaces and the upper and lower combustion chambers.

A full set of grate bars, dead plates and supports, flame bridge plates with bolts and special fire-brick for lining the flame bridges, bridge wall girders and bars, binders and bolts, one damper, the requisite lintels for openings in walls, and all necessary buckstays, tie and anchor rods and anchor plates are provided.

The following fittings and tools are supplied :

Water column fitted with three patent try-cocks with lifting handles and with large size glass water gauge having special shut-off device to operate from fire-room floor, to allow renewal of glass while under pressure. Try-cocks are fitted with steam metal valves arranged for regrinding under pressure.

Independent blow-off pipes for bottom of column and glass gauge, carried down the front, terminating with valve at height of hand.

Steam gauge, 12 inches diameter. Ashcroft—unless otherwise ordered.

Nickel-seated safety valve for each steam drum. Consolidated—unless otherwise ordered.

Drum head stop and check valve for each drum.

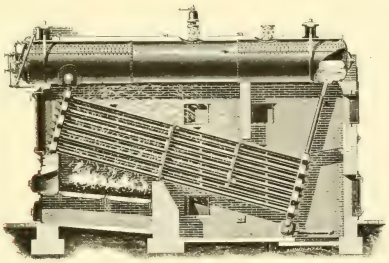
Feed stop valve.

Feed check valve.

Stop valve, ¾ of an inch in diameter, for cleaning pipe connection.

B. & W. Boilers, Continued.

Blow-off valve.
The necessary pipes and fittings for fixing all the above to boiler.
Steel wrench fitting hand-hole nuts.
Tube scraper with handle.
Fire tools, consisting of poker, slice bar and hoe.
Hose and pipe for blowing dust from exterior of tubes.
All materials are of the best quality, each specially adapted to the service required, and the workmanship is first-class in every particular.



Inclined Header Type.

These are made either with **Cast Headers** or **Wrought Steel Headers**; generally, however, vertical headers are cast and inclined headers are wrought.

The following description applies to boilers with "**Inclined Wrought Steel Headers.**" which are specially designed for higher pressures than 160 lbs.

This is the only **Sectional** water tube boiler made up entirely of **Wrought Metal.**

The heating surface of the boiler consists of one or more steam and water drums placed above and connected to a set of sections of four inch tubes. The lower ends of the sections are connected to a mud drum. The connections between all parts are made by expanding wrought tubes into bored tube seats.

All wrought metal for pressure parts, except tubes, is of the best Open Hearth steel, stamped with maker's name, and having a tensile strength of 56,000 to 62,000 pounds per square inch, to show an elongation of not less than 25 per cent. in a parallel test piece of 8 inches accompanied by a reduction in area of at least 50 per cent.; to endure bending double upon itself both before and after being brought to a flanging heat and quenched.

B. & W. Boilers, Continued.

All forgings for pressure parts are made from Open Hearth steel of from 52,000 to 58,000 pounds tensile strength, and formed by hydraulic power.

The cylindrical portion of the drum is made of three sheets, the longitudinal seams butt strapped inside and out. The seams have two rows of rivets passing through both butt straps and the shell, and two rows through the shell aud inner strap only; the butt straps are bent to a proper radius in a hydraulic press. The circular seams are lap-joint, single riveted.

All holes for double-riveted seams are punched $\frac{3}{16}$ inch smaller than the diameter of rivets to be used, and drilled out to full size after the sheets are rolled and assembled with their butt straps.

After drilling, the straps are removed, all burrs cleaned off, and the plates assembled, metal to metal, with parallel turned bolts fitting the holes before riveting.

Each course is built independently to template. The various courses and their heads are assembled by a hydraulic forcing press.

All rivets are driven with hydraulic pressure and held until cool.

All drum heads are fitted with manholes. The heads are hydraulic forged at a single heat, with manhole ring and stiffening plate in position, and have flat raised seats for stand pipe and feed connections. The edges of head and manhole face are turned off true.

The manhole plates and guards are of forged steel. The plate, 11 inches by 15 inches, is faced and turned to a true oval to fit head.

The steam flanges are recessed to make a male and female joint, fitted with stud bolts, with taper threads.

The drum cross boxes are hydraulic forged from a single sheet without seams or rivets.

The sections are built up of 4-inch tubes made of the best knobbled, hammered charcoal-iron blooms, of standard weight.

The tubes are expanded into **Forged Steel** headers of serpentine form, disposing the tubes in a staggered position when assembled in the furnace.

A hand hole of sufficient size to permit the cleaning, removal and renewal of a tube is placed opposite each tube end, said hand hole to have a raised seat milled off to a true surface.

The hand holes are closed on the outside by a forged steel cap milled to a true surface, and are held in position by a forged steel safety clamp, closing the hand-hole opening from the inside, and secured by a ball-headed bolt to insure

B. & W. Boilers, Continued.

correct alignment. All joints are made tight, metal to metal, without packing of any kind.

At customer's option an oval inside fitting hand hole cap can be supplied. The cap and inner surface of header are finished. This form of hand-hole fitting necessitates the use of a thin asbestos gasket. It is preferred by some users because the boiler pressure tends to hold the cap against its seat.

Mud drum is forged steel box seven inches square, which is connected with all of the sections by means of wrought nipples expanded into counterbored seats. The mud drum is tapped for blow off connections on its rear side and furnished with hand holes for cleaning.

Cast iron mud drums can be furnished where the drum is likely to be subjected to corrosion by reason of presence of water at foundation level as in deep basements.

The boiler is suspended, at front and rear, from wrought-iron supporting frames, entirely independent of the setting, to allow for contraction and expansion without straining either the boiler or the brick work, and to allow of repairs or renewal of the latter without disturbing the boiler or its connections.

The front is of ornamental design, consisting of a heavy wrought-iron "I" and channel beam frame fitted with large doors for access to the hand-hole plates and front headers.

The fire fronts have independent frames for fire doors which are bolted on and ash doors are fitted with blast catches. All joints fitted and faces of doors planed.

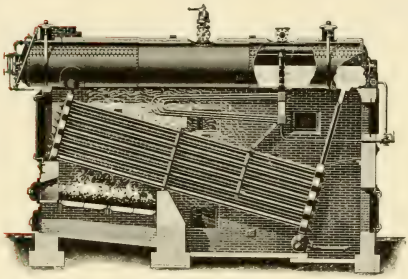
Cast-iron doors in heavy frame are provided for access to back headers. Cast-iron side cleaning doors are provided for access to the tube surfaces and the upper and lower combustion chambers.

A full set of grate bars, dead plates and supports, flame bridge plates with bolts and special fire-brick for lining the flame bridges, bridge wall girders and bars, binders and bolts, one damper, the requisite lintels for openings in walls, and all necessary buckstays, tie and anchor rods and anchor plates are provided.

The same fittings and tools are supplied with this boiler as those previously enumerated for vertical header boilers.

B. & W. Boilers, Continued.

Superheaters.



(Inclined Wrought Steel Header Type, Fitted With Superheater.)

The correct use of superheated steam contemplates not only the prevention of loss through condensation in steam pipes, but the addition of such an amount of superheat to the steam, before it enters the cylinder, as will make up for that robbed by the cylinder walls.

The principles on which a superheater should be constructed, to give a sufficiently high temperature, are :

(1).—The necessity of placing the superheater in a position where a suitable temperature is available. If a boiler is working under economical conditions, the difference between the temperature of saturated steam and of the escaping flue gases leaving a boiler is not sufficient to superheat the steam produced, unless the surface of the superheater be very large : hence, generally speaking, a superheater should not be placed in the flue between boiler and chimney. On the other hand, if placed too near to the boiler furnace, or in a separate furnace, considerable temperature fluctuations may occur, and possibly an excessive temperature may be attained which would cause damage.

(2).—The superheater should be constructed to admit of all its parts expanding and contracting freely, without severe strains being put on any of the joints, which might cause them to leak ; flanged joints, when exposed to furnace gases, should be avoided wherever possible.

B. & W. Boilers, Continued.

(3).—Provision should be made to protect the superheater against overheating when steam is not passing through it sufficiently to carry away the heat supplied by the furnace gases

It will be seen from the illustration that the Babcock & Wilcox Patent Superheater fulfills all these conditions. It is placed in a position where there is practically no deteriorating condensation of the gases, and where the temperature is sufficiently high to insure the steam receiving from 100° to 150° F. of superheat.

This superheater is not subject to the immediate action of the fire, as the furnace gases must first pass through the front part of the boiler, which comprises a considerable heating surface. Assuming the boiler to be in regular work, and the firing even, no great fluctuations in temperature can take place where the superheater is fixed. Moreover, it is readily accessible for examination, and for the renewal of tubes.

There are no flanged joints, all the tube joints are expanded.

Freedom for expansion is provided for by the tubes being free at one end, and by the manifolds not being rigidly connected with each other.

Prevention against overheating during steam raising is insured by the arrangement for flooding with boiler water, and using the superheater as part of the boiler heating surface, while steam is being raised.

As will be seen, the tubes are bent into a "**U**" shape, and connected at both ends with manifolds, one of which receives the natural steam from the boiler, the other collecting the superheated steam after it has traversed the superheater tubes, and delivering it to the valve, placed above the boiler.

The flooding arrangement consists merely of a connection with the water space of the boiler drum, and a three-way cock, by which, at will, the water enters the lower manifold and fills the superheater to the boiler water level. Any steam formed in the superheater tubes is returned into the boiler drum, through the collecting pipe, which, when the superheater is at work, conveys saturated or natural steam into the upper manifold. Prior to opening the superheater stop valve and using superheated steam, the water is drained away from the manifolds by the flooding pipe.

The water in the boiler steam and water drum is, by reason of the fact that it is heated to steam temperature, deprived

B. & W. Boilers, Continued.

of its impurities, hence there is no fear, in flooding the superheater with the boiler water, of the superheater tubes becoming incrustated to any detrimental extent.

A great number of these superheaters have now been at work for some years, and the results lead to the expectation that their durability will leave nothing to be desired.

From 100° to 150° F. of superheat is usually provided for in the proportion of superheating surface to boiler heating surface adopted, and it has been found by experiment that even with the most refined triple expansion engines, working under ordinary conditions, an economy of 10% can be regularly obtained.

With compound engines, especially of slow piston speed such as ordinarily used in a cotton mill, an economy of from 8 to 15% can be obtained by the use of superheated steam.

B. & W. Boilers, Continued.

Tables of Dimensions, Floor Space, Capacities, Etc.

These tables give sizes commonly used, but an infinite number of other sizes are made to meet conditions.

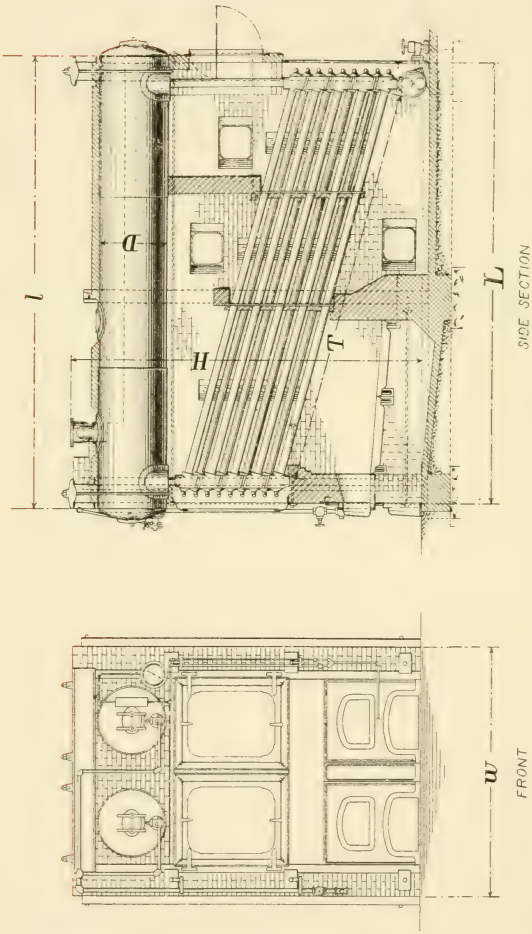
In designing a plant it should be remembered that not more than two boilers should be placed in one battery, and a passageway, not less than three feet wide (for narrow boilers) should be provided on one side of a single boiler, and on both sides of a battery of two boilers, for cleaning purposes. This passageway should be made proportionately larger for wider boilers.

A space should also be left behind the boilers for cleaning purposes and for flue connection. This space to be determined in proportion to the size of the plant, but in no case be less than three feet.

The fire room in front of boilers should not be less than the length of tubes, less 18″. This width of fire room is required for removal of tubes.

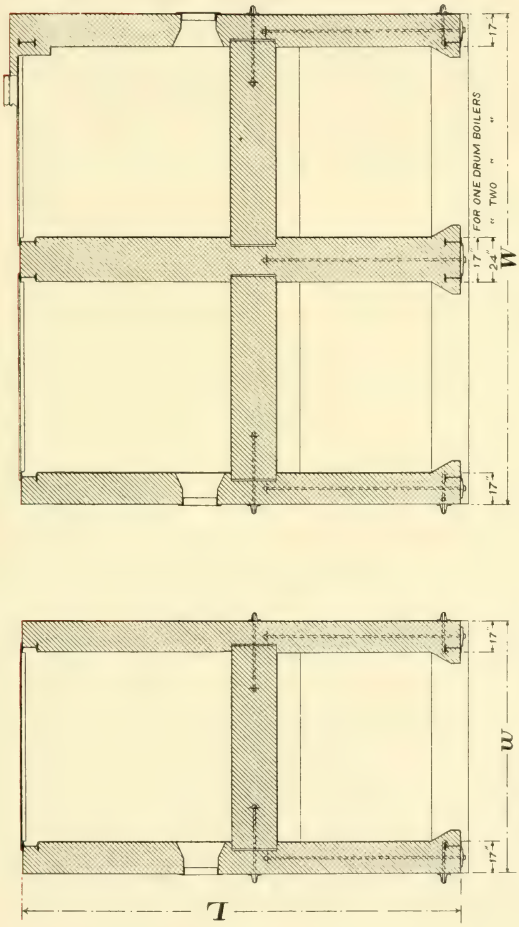
Attention is called to the fact that the **rated horse power** of these boilers is figured on a **basis of ten square feet of heating surface**. Some builders of water tubular boilers try to make their prices appear low by quoting on only seven and a half feet,—which means continuously forcing the boilers, a practice that can not be too strongly condemned.

B. & W. Boilers, Continued.



Vertical Header Type.

B. & W. Boilers, Continued.



Vertical Header Type.

B. & W. Boilers, Continued.

Vertical Header Type.

9 Tubes High (6′-0″ High Furnace.)

Horse Power.	Tubes.			Drums.			Steam Nozzle.		Number of Fire Doors. 1 Boiler.	Length of Setting.	One Boiler.			Two Boilers, (in Battery)		
	Number.	Diameter in inches.	Length in Feet.	Number.	Diameter in inches.	Length.	Diameter.	Height.			Width of Setting.	Number Common Brick.	Number Fire Brick.	Width of Setting.	Number Common Brick.	Number Fire Brick.
			T		D	l		H		L	w			W		
76	45	4	14	1	36	16′-5⅝″	5″	14′-8″	1	15′-10″	6′- 1″	12400	2800	10′- 9″	17500	5600
102	54	4	16	1	36	18′-4¾″	5″	14′-8″	1	17′-9½″	6′- 8″	14200	3150	11′-11″	20300	6300
114	54	4	18	1	36	20′-4 ″	5″	14′-8″	1	19′-9 ″	6′- 8″	15700	3450	11′-11″	22300	6900
132	63	4	18	1	36	20′-4 ″	5″	14′-8″	1	19′-9 ″	7′- 3″	16000	3700	13′- 1″	23000	7400
151	72	4	18	1	42	20′-4 ″	5″	15′-2″	1	19′ 9 ″	7′-10″	16600	3950	14′- 3″	24000	7900
169	81	4	18	1	42	20′-4 ″	6″	15′-2″	1	19′-9 ″	8′- 5″	16700	4100	15′- 5″	24300	8200
193	90	4	18	2	36	20′-4 ″	8″	15′-8″	2	19′-9 ″	9′- 0″	16900	3900	17′- 2″	28500	7800
229	108	4	18	2	36	20′-4 ″	8″	15′-8″	2	19′-9 ″	10′- 2″	17400	4250	19′- 6″	29500	8500
264	126	4	18	2	36	20′-4 ″	8″	15′-8″	2	19′-9 ″	11′- 4″	17900	4700	21′-10″	30500	9400
302	144	4	18	2	42	20′-4 ″	8″	16′-2″	3	19′-9 ″	12′- 6″	18900	4900	24′- 2″	32400	9800
338	162	4	18	2	42	20′-4 ″	10″	16′-4″	3	19′-9 ″	13′- 8″	19500	5200	26′- 6″	33600	10400

Note:—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

B. & W. Boilers, Continued.

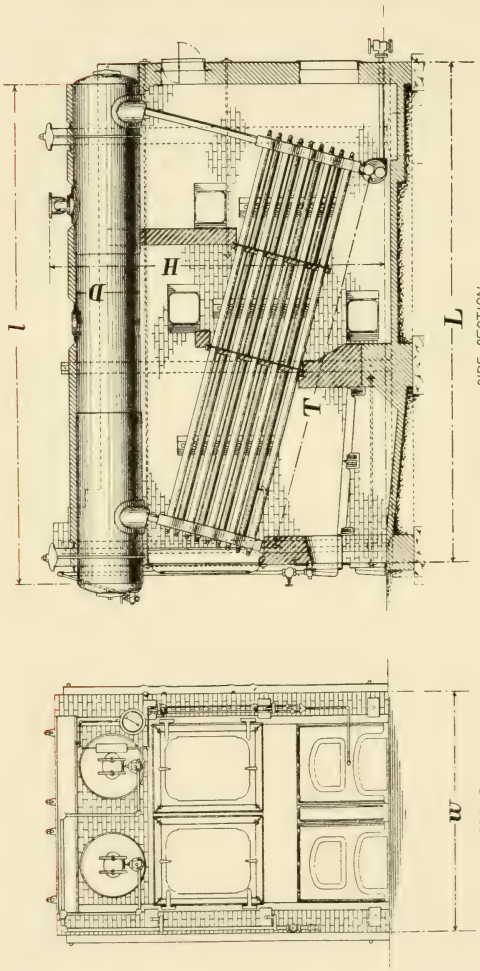
Vertical Header Type.

12 Tubes High (6′-0″ High Furnace.) Double Deck.

Horse Power.	Tubes.			Drums.			Steam Nozzle.		Number of Fire Doors. 1 Boiler.	Length of Setting.	One Boiler.				Two Boilers, (in Battery.)		
	Number.	Diameter in inches.	Length in feet.	Number.	Diameter in inches.	Length.	Diameter.	Height.			Width of Setting.	Number Common Brick.	Number Fire Brick.	Width of Setting.	Number Common Brick.	Number Fire Brick.
			T		D	l		H		L	w			W		
220	168	4	18	1	42	20′-4″	6	17′-6″	1	19′-9″	8′-5″	19000	4800	15′- 5″	27350	9600
251	120	4	18	2	36	20′-4″	8	18′-0″	2	19′-9″	9′-6″	18950	4450	17′- 2″	31700	8900
297	144	4	18	2	36	20′-4″	8	15′-0″	2	19′-9″	10′-2″	19500	4800	19′- 6″	32750	9600
347	168	4	18	2	42	20′-4″	8	18′-6″	2	19′-9″	11′-4″	20400	5100	21′ 10″	34450	10200
394	192	4	18	2	42	20′-4″	8	18′-6″	3	19′-9″	12′-6″	20900	5450	24′- 2″	35500	10900
440	216	4	18	2	42	20′-4″	10	18′-8″	3	19′-9″	13′-8″	21400	5650	26′- 6″	36650	11300
516	252	4	18	3	36	20′-4″	10	18′-6″	3	19′-9″	15′-5″	21950	6000	30′- 0″	37800	12000

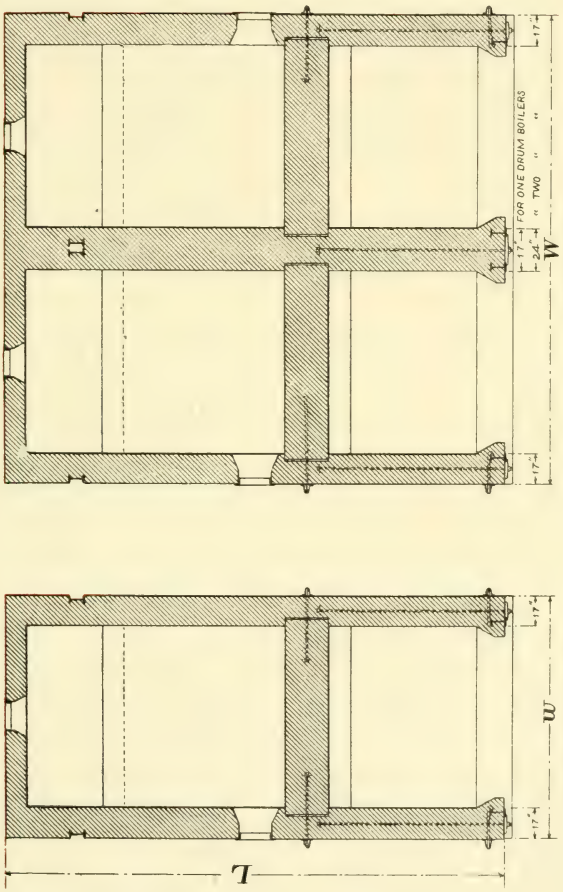
Note:—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

B. & W. Boilers, Continued.



Inclined Header Type.

B. & W. Boilers, Continued.



Inclined Header Type.

B. & W. Boilers, Continued.

Inclined Header Type.

9 Tubes High (6'-0" High Furnace.)

Horse Power.	Tubes.			Drums.		Steam Nozzle.		Number of Fire Doors. 1 Boiler.	Length of Setting.	One Boiler.				Two Boilers, (in Battery.)		
	Number.	Diameter in inches.	Length in feet.	Number.	Diameter in inches.	Length.	Diameter.	Height.			Width of Setting.	Number Common Brick.	Number Fire Brick.	Width of Setting.	Number Common Brick.	Number Fire Brick.
			T		D	L		H	L		w			W		
76	45	4	14	1	36	19'-1 3/8"	5"	14'-8"	1	19'-0"	6'-1"	15300	2810	10'-9"	22100	5620
103	54	4	16	1	36	21'-2 1/8"	5"	14'-8"	1	21'-5"	6'-8"	17300	3090	11'-11"	25400	6180
116	54	4	18	1	36	23'-3 3/8"	5"	14'-8"	1	23'-5"	6'-8"	19000	3400	11'-11"	27700	6800
133	63	4	18	1	36	23'-3 3/8"	5"	14'-8"	1	23'-5"	7'-3"	19400	3590	13'-1"	28600	7180
153	72	4	18	1	42	23'-3 3/8"	5"	15'-2"	1	23'-5"	7'-10"	20500	3780	14'-3"	29700	7560
170	81	4	18	1	42	23'-3 3/8"	6"	15'-2"	1	23'-5"	8'-5"	21000	3990	15'-5"	30500	7770
196	90	4	18	2	36	23'-3 3/8"	8"	15'-8"	2	23'-5"	9'-0"	21000	3720	17'-6"	35900	7440
231	108	4	18	2	36	23'-3 3/8"	8"	15'-8"	2	23'-5"	10'-2"	21900	4000	19'-6"	37400	8000
267	126	4	18	2	36	23'-3 3/8"	8"	15'-8"	2	23'-5"	11'-4"	22600	4410	21'-10"	38200	8820
305	144	4	18	2	42	23'-3 3/8"	8"	16'-2"	3	23'-5"	12'-6"	23600	4700	24'-2"	41200	9400
341	162	4	18	2	42	23'-3 3/8"	10"	16'-4"	3	23'-5"	13'-8"	24800	5090	26'-6"	43500	10180

Note:—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

B. & W. Boilers, Continued.

Inclined Header Type.

10 Tubes High (6′-0″ High Furnace.)

Horse Power.	Tubes.			Drums.			Steam Nozzle.		Number of Fire Doors. 1 Boiler.	Length of Setting.	One Boiler.			Two Boilers (in Battery.)		
	Number.	Diameter in inches.	Length in feet.	Number.	Diameter in inches.	Length.	Diameter.	Height.			Width of Setting.	Number Common Brick.	Number Fire Brick.	Width of Setting.	Number Common Brick.	Number Fire Brick.
			T	D	l		H		L	w			W		
168	80	4	18	1	42	23′–5″	5″	15′–8″	1	23′–5″	7′–10″	21350	3900	14′– 3″	30600	7800
188	90	4	18	1	42	23′–5″	5″	15′–8″	1	23′–5″	8′– 5″	21600	4000	15′– 5″	31400	8000
215	100	4	18	2	36	23′–5″	8″	16′– 2″	2	23′–5″	9′– 0″	21650	3850	17′– 2″	34900	7700
253	120	4	18	2	36	23′–5″	8″	16′–2″	2	23′–5″	10′– 2″	22750	4100	19′– 6″	38650	8200
294	140	4	18	2	36	23′–5″	8″	16′–2″	2	23′–5″	11′– 4″	23250	4500	21′–10″	39200	9000
333	160	4	18	2	36	23′–5″	8″	16′–2″	3	23′–5″	12′– 6″	24800	5000	24′– 2″	43350	10000
376	180	4	18	2	42	23′–5″	8″	16′–8″	3	23′–5″	13′– 8″	25500	5200	26′– 6″	51000	10400
440	210	4	18	3	36	23′–5″	8″	16′ 2″	3	23′–5″	15′– 5″	26700	5250	30′– 0″	46450	10500

Note:—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

B. & W. Boilers, Concluded.

Inclined Header Type.

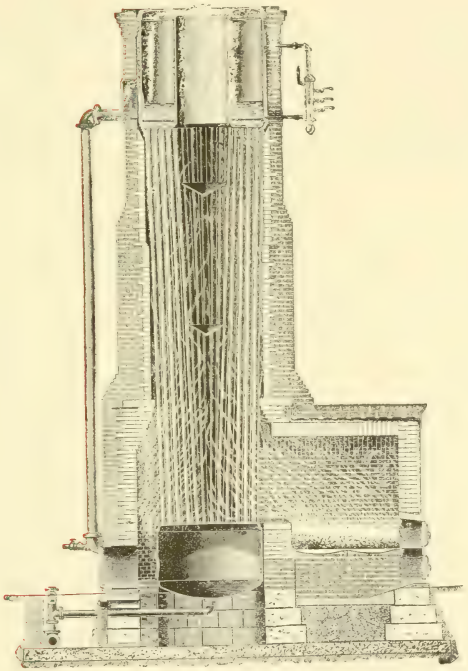
12 Tubes High (6′-0″ High Furnace). Single Deck.

Horse Power.	Tubes.			Drums.			Steam Nozzle.		Number of Fire Doors. 1 Boiler.	Length of Setting.	One Boiler.				Two Boilers, (in Battery.)		
	Number.	Diameter in inches.	Length in feet.	Number.	Diameter in inches.	Length.	Diameter.	Height.			Width of Setting.	Number Common Brick.	Number Fire Brick.		Width of Setting.	Number Common Brick.	Number Fire Brick.
			T		D	L		H		L	w				W		
222	108	4	18	1	42	23′-3⅝″	6″	16′-8″	1	23′-5″	8′-5″	23350	4450		15′-5″	33200	8900
253	120	4	18	2	36	23′-3⅝″	8″	17′-2″	2	23′-5″	9′-0″	22950	4350		17′-2″	39000	8700
300	144	4	18	2	36	23′-3⅝″	8″	17′-2″	2	23′-5″	10′-2″	24350	4700		19′-6″	40850	9400
350	168	4	18	2	42	23′-3⅝″	8″	17′-8″	2	23′-5″	11′-4″	24700	5000		21′-10″	42850	10000
397	192	4	18	2	42	23′-3⅝″	8″	17′-8″	3	23′-5″	12′-6″	25750	5500		24′-2″	44650	11000
443	216	4	18	2	42	23′-3⅝″	10″	17′-10″	3	23′-5″	13′-8″	26900	6000		26′-6″	47150	12000
520	252	4	18	3	36	23′-3⅝″	10″	17′-2″	3	23′-5″	15′-5″	28550	5950		30′-0″	50000	11900

Note:—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

Cahall Water Tube Boiler.

(Vertical.)



This type of Boiler is convenient to use when space is limited, or where water is very bad. The circulation is positive and unintermittent, the freedom from formation of scale within the tubes in heavy masses, and the freedom from the accumulation of foreign substances outside of the tubes owing to their vertical position, with good capacity and good efficiency, are the leading points in favor of this type of Boiler.

Cahall Vertical Boilers, Continued.

The construction is shown by the accompanying cut. It consists of two drums, arranged one above the other, made of best mild, open-hearth flange steel, and connected with 4″ lap-welded charcoal iron tubes. These tubes are vertical, are straight throughout their entire length, and are expanded into the drums at each end.

The water line in the upper drum is about two feet above the bottom of the drum, the drum itself being about seven feet high in the clear inside, leaving a space of five feet between the surface of the water and the point at which the steam is drawn off from the boilers, which prevents the carrying over of water with the steam, either in the form of supersaturation or mechanical entrainment.

An external circulating pipe comes out from the upper, or steam, drum, just below the water level, and is carried downward, outside the brick work, to a point just below the tube sheet of the lower drum, where it enters that drum.

The boiler rests upon four iron brackets, riveted to the lower, or mud, drum, supported upon four piers of the foundation, the entire structure standing without contact with the brick work, allowing the boiler freedom for expansion, without straining the brick setting. Where pipe connections are made to the boilers through the walls, they are encased in expansion boxes.

Owing to the fact that the gases escape through the central opening in the upper drum, the upper tube sheet has a circular opening in its center, leaving a central open space between the tubes, which gradually narrows to the bottom tube sheet. Advantage is taken of this space, which is in the form of an inverted cone, to introduce deflecting plates, which, in connection with corresponding baffles or offsets in the brick casing, cause the gases to be alternately thrown out and in throughout the heating surface.

It is proper to say that the erection of these boilers is quite a proposition in a Southern point where suitable rigging is difficult to obtain, not to mention men familiar with that class of work ; that the brick arches to the furnace are subjected to a very powerful heat and consequently the renewal of these is an item ; the gauge glasses are inconveniently high up to be properly watched and observed even with a good light. Its sphere of usefulness is unquestionably greater in large cities where space is a considerable item, than in town or country cotton mills, but occasionally cases do exist where it can be used to advantage.

Cahall Vertical Boilers, Continued.

Table of Standard Sizes.

Horse Power.	Heating Surface. Square Feet.	Steam Drum. Diameter. Inches.	Steam Drum. Height. Inches.	Mud Drum. Diameter. Inches.	Mud Drum. Height. Inches.	Diameter of Smoke Flue. Inches.	Tubes. Number.	Tubes. Diameter. Inches.	Tubes. Length. Feet.	Steam Open'g. Diameter. Inches.	Steam Open'g. Flange. Inches.	Safety Valve. Number.	Safety Valve. Diameter. Inches.	Feed Pipe. Inches.	Blow Off Pipe. Inches.	Furnace. Width. Feet.	Furnace. Long. Feet.	Furnace. Sq. Feet of Grate Surface.	Smoke Stack. Diameter. Inches.	Smoke Stack. Height. Feet.
60	615	54	68	42	48	20	40	4	11	4	10	1	3	1½	2	5	3	15	24	50
75	782	54	68	42	48	20	40	4	15	4	10	1	3	1½	2	5	3½	17½	24	50
100	1110	66	72	54	48	28	61	4	10	5	11	1	4	1½	2½	6	3½	21	32	50
125	1311	66	72	54	48	28	61	4	10	5	11	1	4	1½	2½	6	4	24	32	50
150	1550	72	78	60	48	32	80	4	18	5	11	2	3	1½	2½	7	4½	31½	36	50
175	1801	72	78	60	48	32	80	4	21	6	13	2	3	2	2½	7	5	35	36	50
200	2084	80	84½	68	49	31	108	4	18	6	13	2	3½	2	2½	8	5	40	38	60
250	2536	80	84½	68	49	31	108	4	22	8	15	2	4	2	2½	8	6	48	38	60

Note:—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purposes of installation.

Cahall Vertical Boilers, Concluded.

Table Showing Floor Space and Brick Required to Set.

Horse Power.	Length. Feet and Inches.	Width. Feet and Inches. 1 Boiler.	2 Boilers In Battery.	3 Boilers In Battery.	4 Boilers In Battery.	5 Boilers In Battery.	Height from floor to top of brick work. Feet and Inches.	Height from floor to top of steam flange. Feet and Inches.	Brick Required. For 1 Boiler. Red Brick.	Fire Brick. First Quality.
60	11 8	7 10	11 4	20 10	27 4	33 10	23 0	23 6	7600	3945
75	12 2	7 10	11 4	20 10	27 4	33 10	27 0	27 6	8800	4465
100	13 6	9 8	17 2	24 8	32 2	39 8	25 6	26 2	15450	4645
125	14 0	9 8	17 2	24 8	32 2	39 8	28 6	29 2	16005	5250
150	15 4	10 8	19 2	27 8	36 2	44 8	28 0	28 8	18250	5795
175	15 10	10 8	19 2	27 8	36 2	44 8	31 0	31 8	20550	6380
200	16 7	11 8	21 2	30 8	40 2	49 8	28 3	28 11	21800	6750
250	17 7	11 8	21 2	30 8	40 2	49 8	32 3	32 11	26000	7065

Battery of 2 Boilers requires double amount of fire brick and double amount, less 10% of common brick. Other batteries of 3, 4, 5, etc., in the same proportion.

HORIZONTAL FIRE TUBULAR BOILERS.

(Only the horizontal type of fire tubular boilers is considered, as customers whose conditions dictate the use of vertical boilers can obtain better results and more satisfaction with vertical water tubular boilers.)

This type of boiler has been very largely used in the South. Until recently cotton mills were generally equipped with single cylinder non-condensing Corliss engines and fire tubular boilers steaming at 80 to 100 pounds pressure. For this class of work almost any of the firms buildings this type of boiler were capable of turning out a satisfactory article on their own specifications.

Now, however, that higher grade steam plants are the rule, involving the use of boiler pressures ranging from 125 to 200 pounds pressure per square inch, when this type of boiler is used too great care can not be exercised in having the boilers built not only by a reputable builder with the proper facilities for constructing them, but also that they should be made according to the most rigid specifications.

Those of the Hartford Steam Boiler Inspection and Insurance Company are probably the best. Their large experience in inspecting boilers has suggested and emphasized the desirability of the points incorporated in their specifications. This chapter on fire tubular boilers, therefore, is derived largely from their requirements.

There has always been some confusion and misunderstanding of the terms employed to designate the different styles of fronts. It is suggested, therefore, that for the sake of uniformity the following designations be employed:

A **Full Flush Front**, is, as its name would indicate, a flush flat front covering the entire brick work of the boiler setting, and the shells of the boilers do not extend through it to form the smoke connection.

A **Half Arch Front** is one extending only to the center line of the shell of the boiler, which is of the "overhanging type"; it leaves the upper part of the brick work of the boiler setting exposed to view.

A **Full Arch Front** is the same as the half arch, with the addition of a top arch plate to square up the front and to cover the upper part of the brick setting.

Horizontal Fire Tubular Boilers, Continued.

Boiler Ratings, Calculations, Etc.

By common consent, horizontal fire tubular boilers of certain dimensions have become arbitrarily designated as of certain horse powers, regardless of the number and size of the tubes. In the following tables, therefore, boilers are rated in this customary manner. For the benefit of those, however, who are disposed to be more accurate and to calculate, the following rule will apply :

Ascertain the heating surface in the boiler by multiplying two-thirds of its circumference by its length in inches, and add to it the area of all the tubes. Divide this heating surface by fifteen, which is a fair average of the ratio between the heating surface and its capacity in horse power.

Strictly speaking, a standard horse power is the evaporation of thirty pounds of water per hour from a feed water temperature of 100 degrees Fahrenheit into steam at 70 pounds gauge pressure.

The safe working pressure for a fire tubular boiler can be ascertained by multiplying one-sixth the tensile strength of the plate by the thickness of the plate, and dividing by one-half the diameter of the boiler.

The thickness of the plate is obtained by multiplying the pounds steam pressure that is intended to be carried by half the diameter of the boiler in inches and by a factor of safety of 5 ; and this product divided by the tensile strength of the plate, multiplied by 86 per cent., which is assumed as the efficiency of a triple riveted, butt, strapped joint plate. Example : It is found by the above rule that a 72 inch boiler to carry a working pressure of 125 lbs. to the square inch, the tensile strength of the steel being 60,000 lbs., requires a shell $\frac{7}{16}$ in. thick.

Table for "Standard Boilers."

(For pressures up to and including 100 lbs. gauge pressure.)

	Horse Power, as usually rated.											
	40	45	50	60	60	70	80	90	100	125	125	150
Diameter of boiler in inches.	48	48	54	54	60	60	60	66	66	66	72	72
Length of tubes in feet.	12	14	12	15	12	14	16	15	16	18	16	18
Number of 4 inch tubes.	24	24	30	30	44	44	44	54	54	54	70	70
Number of 3½ inch tubes.	28	28	44	44	54	54	54	66	66	66	86	86
Thickness of Shell.	5/16	5/16	5/16	5/16	3/8	3/8	3/8	7/16–3/8	7/16–3/8	7/16–3/8	7/16	7/16
Thickness of Heads.	3/8	3/8	3/8	3/8	7/16–1/2	7/16–1/2	7/16–1/2	1/2	1/2	1/2	1/2	1/2
Diameter of smoke stack.	24	24	26	26	28	28	28	30	30	34	34	30
Length of smoke stack in feet.	40	50	40	50	40	50	60	60	60	60	60	66

Longitudinal seams in the above are either double or triple riveted and lap joints.

Alternate Table for Pressures of 125 lbs.

Thickness of Shell.	5/16	5/16	3/8	3/8	3/8	3/8	3/8	7/16	7/16	7/16	1/2	1/2
Thickness of Heads	7/16	7/16	7/16	7/16	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2

Longitudinal seams in the above are triple riveted and butt joints with inside and outside covering straps.

Alternate Table for Pressures of 150 lbs.

Thickness of Shell.	3/8	3/8	3/8	3/8	7/16	7/16	7/16	1/2	1/2	1/2	1/2	1/2
Thickness of Heads.	7/16	7/16	7/16	7/16	1/2	1/2	1/2	9/16	9/16	9/16	9/16	9/16

Longitudinal seams in the above are triple or quadruple riveted and butt joints with inside and outside covering straps.

Horizontal Fire Tubular Boilers, Continued.

Hartford Steam Boiler Inspection and Insurance Company's Specifications.

Type and General Dimensions.—The boilers to be of the Horizontal Fire Tubular type, set with either Overhanging or Full Flush Fronts, with all parts and pieces designed according to our detailed specifications for high pressure work.

Materials, Quality, Thickness and Tests.—Shell plates to be of our standard thickness on the edges, of open-hearth fire box steel, having a tensile strength of not less than 57,000 pounds, nor more than 62,000 pounds per square inch of section, with not less than fifty-six per cent. of ductility as indicated by contraction of area at point of fracture under test, and by an elongation of twenty-five per cent. in a length of 8 inches. Heads of corresponding thickness, of best open-hearth flange steel. All plates, both of shells and heads, must be plainly stamped with name of maker, brand, and tensile strength; brands to be so located that they may be seen on plates after the boilers are finished. Each shell plate must bear a coupon which shall be sheared off, finished up and tested by the maker of the boiler, at his own expense. Each coupon must fulfill the above requirements as to strength and ductility. It also must stand bending down when cold, when red hot, and after being heated red hot and quenched in cold water, without signs of fracture. All plates failing to pass these tests will be rejected. All tests and inspections of material should be made at the place of manufacture before shipment. A certified copy of report of tests to be furnished both to the customer and to the Hartford Steam Boiler Inspection and Insurance Company.

Riveting.—The longitudinal seams of boilers must be triple riveted, butt joint type, with double covering strips. They must be arranged to come well above the fire line of boiler and must break joints in the different courses in the usual manner. All dimensions and proportions are to be as per our standard. The girth seams are to be of single rivet, lap-joint type, properly spaced. The rivet holes must be drilled in place; that is, holes punched at least $\frac{1}{4}''$ less than full size, then courses rolled up, covering plates and heads bolted to courses, with all holes together perfectly fair; then rivet holes drilled to full size; then plates taken apart and the burr removed. No rivets shall be driven in unfair holes: such

Horizontal Fire Tubular Boilers, Continued.

holes must be brought in line with a reamer; if a drift pin is used for this purpose, the boilers will be rejected.

Braces.—These must be strictly according to our standard Above the tubes on front head, and on back head, each of crow-foot form, flat or round in body. None of them shall be less than 3 feet 6 inches long, and each must be fastened to shell and heads by two rivets at each end, or solid steel braces of approved pattern and equal strength to the above, may be used. Care must be exercised in setting them, that they bear uniform tension.

Braces Below Tubes.—There must be four braces below the tubes in each boiler Two of these are to be through braces extending from head to head. The front end of brace to be upset, threaded, and secured to front head with a nut and washer on both inside and outside of head. The two remaining braces are to be secured to rear head in the same manner as the through braces. The front end of brace to be extended forward, fitted to side of shell, and riveted there with two rivets, all to be substantially as shown in our standard diagram for the proper size of boiler.

Tubes: Size. Number, and Arrangement.—These are to be set in vertical and horizontal rows, with a clear space between them, vertically and horizontally, all as per our standard diagram, and are to be the best lap-welded tubes. Holes for tubes to be neatly chamfered off on outside. Tubes to be set with a dudgeon expanded, and beaded down at each end.

Manholes.—Each boiler to have two manholes—one located in top of shell and another located in front head below tubes, each to have a strong frame and suitable plate, yoke, and bolt, the proportions of the whole to be such as will make it strong as any other portion of the shell of like area.

Boiler Supports—Each boiler to be suspended from wrought-iron or steel I beams, by means of eye or U bolts and plate loops, securely riveted to boiler shell. The I beams are to be supported on cast-iron columns of square or rectangular section. Each pair of beams to be connected together, 3″ apart, by tie-bolts and cast-iron separators, one separator near each end, and others at intervals of about five feet. The whole system of suspension should be made in the best manner, properly arranged to allow free expansion of the boilers, securely held and supported in every direction, amply strong in every part and furnished complete.

Nozzles.—Each boiler must have two cast-steel nozzles, of proper diameter to fit the boiler in question—one for steam pipe connection, the other for safety valve connection—each

Horizontal Fire Tubular Boilers, Continued.

accurately squared on top flange, and securely riveted to boiler shell.

Smoke Opening.—Each boiler to have an opening of standard size cut out of front connection on top for attachment of uptake to flue.

Feed Pipe.—Each boiler to have a hole tapped for suitable sized pipe in front head, above the top or upper row of tubes, for feed connection. The feed pipe shall extend from front head back to within two feet of back head of boiler: thence across the boiler to near shell on right hand side. On this end is to be placed an elbow, with outlet pointed down. Feed pipe to be properly hung from braces.

Blow-Off Pipe Connection.—Each boiler to have a circular plate of shell steel, one-half inch thick, of suitable diameter, riveted to bottom of shell, tapped to receive the blow-off pipe.

Fusible Plug.—Each boiler to be provided with fusible plug in back head, two inches above top of upper row of tubes.

Fittings.—Each boiler to be provided with one Pop safety valve, one "S" steam gauge, three gauge cocks, and one gauge glass, all to be of approved pattern and size, and the necessary holes to be made for their proper connection. If combination water column is used, the steam and water connection between it and the boiler must be made by pipes not less than $1\frac{1}{4}$″ in diameter.

Castings for Setting.—Each boiler to be provided with a cast-iron front, with all necessary anchor bolts of suitable length; closely fitting front connection doors, with suitable fastenings to prevent warping; closely fitting furnace doors, with liner plates; back connection door 16″x24″, with liner plates; grate bars for grate, of pattern to be selected by purchaser, to be of the same width as the boiler, with suitable bearer bars for same; arch bars for back connection, and all buck staves, with the necessary bolts or tie-rods, and all other castings or iron work necessary for the proper setting of the boiler complete.

In General.—The size and description of parts are to conform to the details of our standard diagram and circulars, which will be furnished on application for any size of boiler. All material and workmanship to be subjected to the inspection and approval of the Hartford Steam Boiler Inspection and Insurance Company.

Horizontal Fire Tubular Boilers, Continued.

Notes On Boiler Specifications.

The above specification is made for boilers suspended by straps. An alternate specification would provide that boilers must have four cast-iron brackets, two on each side, securely riveted in place, each 12″ long, for boilers up to 66″ in diameter; and three lugs on each side for those 72″ in diameter. Cast iron wall plates of ample size and weight must be furnished for each bracket to rest upon, and three rollers 1″ in diameter and of suitable length must be furnished for all except the front bracket to rest upon so as to provide for frequent expansion of the boiler.

Stacks and smoke connections should always be separately specified, and should not be considered included in a price without being distinctly so stated. Special conditions in each case affect both the kind of smoke connection and kind of stack, if any, required. Where, however, stacks are to be included for individual or pairs of boilers, specify galvanized wire rope guys to be four times the length of the stack.

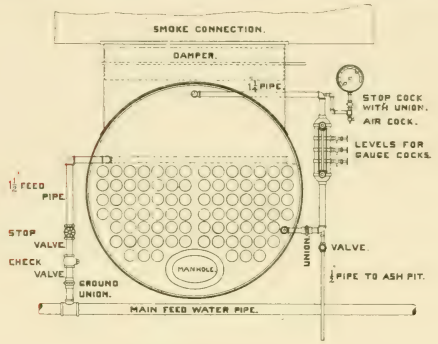
Whistles also should be the subject of special specification, as cotton mill owners have different ideas on this subject. Some want chime whistles, some prefer plain whistles, and some care for none at all. Then, of course, in the case of boilers ordered for additions to existing plants, no whistle would probably be required.

All **valves** that are to be included in boiler specifications should be distinctly stated, as none are ordinarily included except the safety valve. The other valves ordinarily required for single boilers, however, are asbestos plug cocks for blow-off valves, check valves, and main steam or stop valves. These will be discussed, however, under the subject of piping, under another heading.

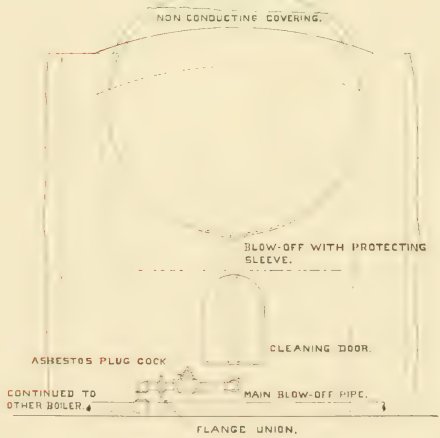
One set of **firing tools** as ordinarily specified includes a poker, hoe and slice bar.

Horizontal Fire Tubular Boilers, Continued.

Water Columns, Feed Pipes, Blow Offs, Etc.



(Diagram, Front View.)



(Diagram, Rear View.)

Connections to Water Column should not be less than 1¼″. The lower gauge cock on Water Column should be 3″ above the top of the upper row of tubes.

Horizontal Fire Tubular Boilers, Continued.

On boilers 60″ or more in diameter, the feed-pipe should not be less than 1½″.

On boilers from 54″ to 42″ in diameter, the feed-pipe should not be less than 1¼″;—36″ or less in diameter, 1″.

The internal feed-pipe should be supported from the braces or the shell and not rest upon the tubes.

Blow-off must have protecting sleeve, as indicated by dotted lines.

Blow-off should be 2″, or when water is bad, 2½″, and under rare circumstances 3″.

Steam Outlets.—There should be two cast steel nozzles or steel flanges securely riveted to the boiler shells, one near each end; both should be of the same size, though one is for the safety valve and the other for the steam connection. When cast steel nozzles are used, blank companion flanges should be furnished by the maker; when steel flanges are used no companion flanges are needed, as the flanges are themselves threaded for screwed pipe connections.

Table Showing Sizes of Steam Outlets and Safety Valves.

(In inches.)

Diameter of Boiler.	Size of Steam Outlets	Safety Valves.	
		Pop.	Levit.
48	4	3	3½
54	4	3	3½
60	5	3½	4
66	5	3½	5
72	6	4	5

Steam Drums and Steam Domes.—Steam Domes are no longer used on boilers; even where but one boiler is used, it is better to put up a short length of steam drum. Steam drums should be twenty-five per cent. larger in area than the combined area of all the steam openings in boilers connected to it. The steam drum should be connected to the boilers by long bend cast iron flanged fittings, or by bent steel elbows,

Horizontal Fire Tubular Boilers, Continued.

the latter preferably. The stop valves to each boiler intended for using over 100 pounds pressure, should be of the high pressure gate type, with yokes and outside screws.

Mud Drums.—Mud Drums are out of date and should not be used. The requirement already noted under "Rules for the Management and Care of Boilers," that boilers should be blown off twice each day, much more satisfactorily takes care of any mud deposited.

Smoke Connections.—A horizontal sheet iron or steel smoke connection should connect the boilers to the stack. A damper should be placed in the uptake from each boiler to the smoke connection, and an improved damper regulator should be placed in the engine room under the supervision of the engineer; the use of the damper regulator has in some notable instances effected a saving of as much as fifteen per cent. in the use of fuel.

Stacks.—The proper draft for boilers is secured either naturally by the use of the brick or iron stack, or artificially by a Mechanical Draft outfit. The latter will be considered under its proper heading, also brick stacks under the head of Mill Engineering.

When steel stacks are used, they may still be erected on top of the boiler setting, properly guyed; but the best practice is largely in favor of erecting the stack to one side of the boiler setting on a brick base of its own, either guyed or self-supporting as may be desired. When a steel stack is so erected, the brick base should be carried up higher than the horizontal smoke flue that leads into it; a cast iron flanged base plate securely held down by foundation bolts connects the metal stack to the brick base.

The objections to iron stacks erected on the boiler setting are:

(1). Rain will drive in or leak in, and coming down on the tube ends causes rapid deterioration.

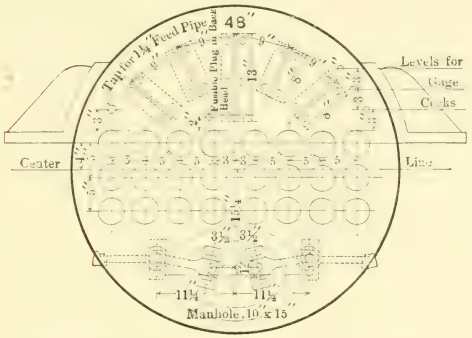
(2). Strong winds cause the stack to vibrate and loosen up and crack the brick work of the boiler setting.

(3). No satisfactory damper arrangement is practicable.

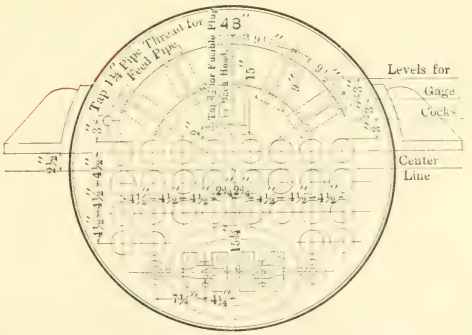
Horizontal Fire Tubular Boilers, Continued.

Tube Spacing and Head Bracing,

Designed and advocated by the Hartford Steam Boiler Inspection & Insurance Co.

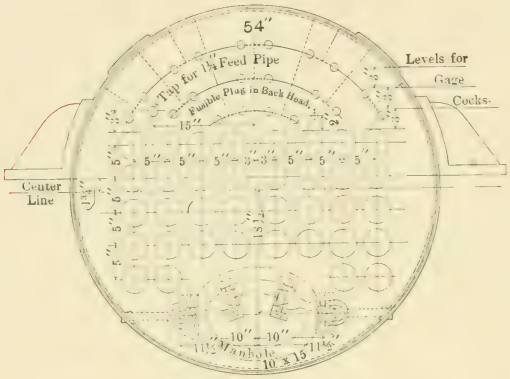


Diameter 48 in. Twenty-four 4-in. Tubes.

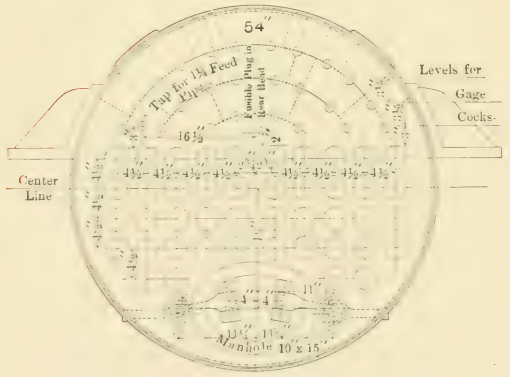


Diameter 48 in. Twenty-eight 3½-in Tubes.

Horizontal Fire Tubular Boilers, Continued.

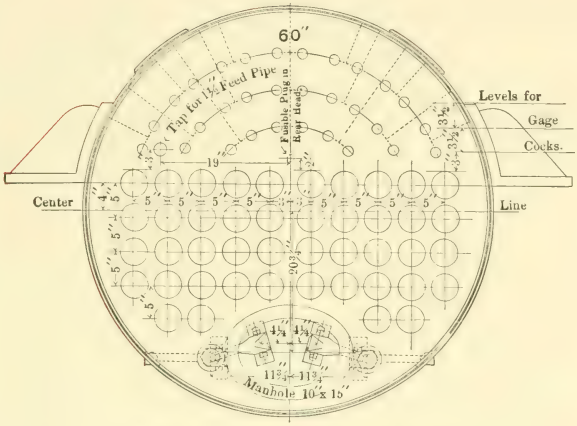


Diameter 54 in. Thirty-six 4-in Tubes.

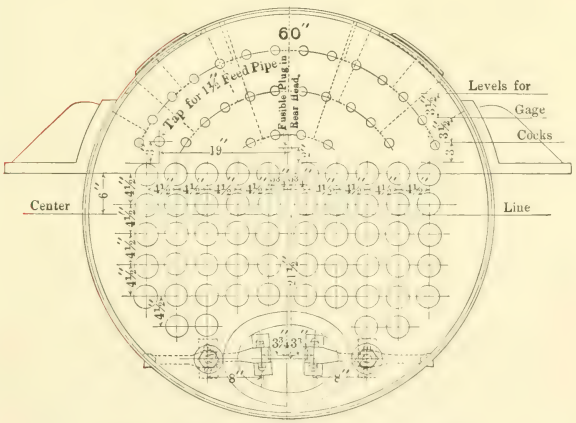


Diameter 54 in. Forty-four 3½-in Tubes.

Horizontal Fire Tubular Boilers, Continued.

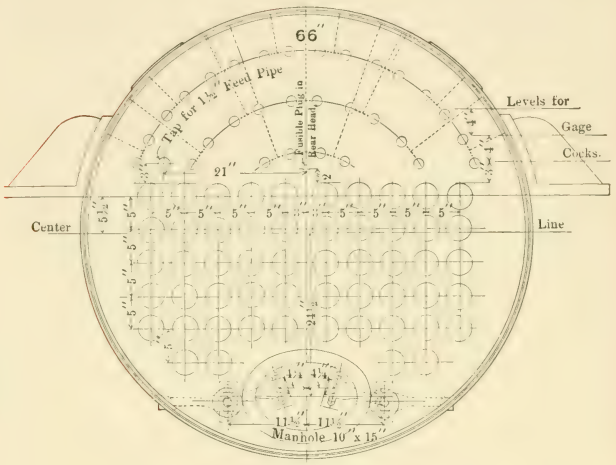


Diameter 60 in. Forty-four 4-in. Tubes.

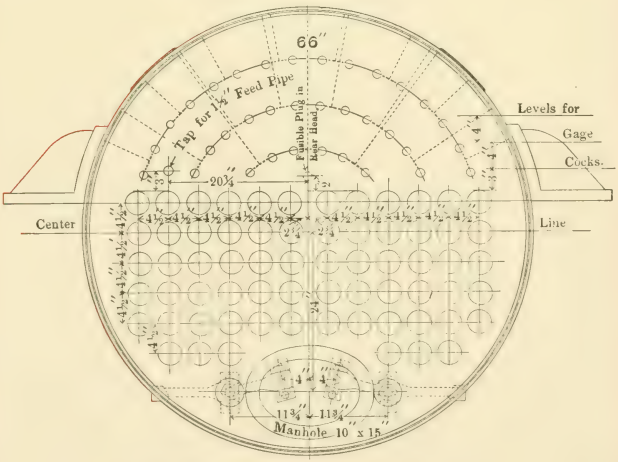


Diameter 60 in. Fifty-four 3½-in. Tubes.

Horizontal Fire Tubular Boilers, Continued.

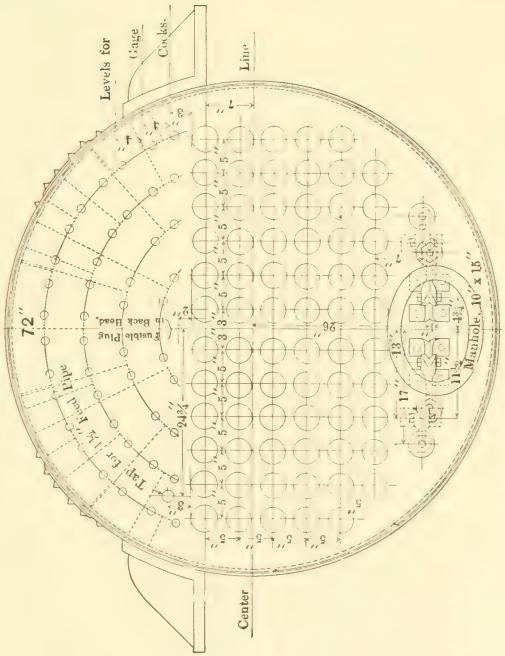

66″
Tap for 1½″ Feed Pipe
Fusible Plug in Rear Head
Levels for Gage Cocks.
21″
24″
Center Line
5½″
5″ – 5″ – 5″ – 5″ – 5″ – 5″ – 5″ – 5″ – 5″ – 5″ – 5″
5″ + 5″ + 5″ + 5″
24½″
4¼″ 4¼″
11½″ – 11½″
Manhole 10″ x 15″

Diameter 66 in. Fifty-four 4-in. Tubes.


66″
Tap for 1½″ Feed Pipe
Fusible Plug in Rear Head
Levels for Gage Cocks.
20¾″
24″
Center Line
4½″ – 4½″ – 4½″ – 4½″ – 4½″ – 4½″ – 4½″ – 4½″ – 4½″ – 4½″ – 4½″
2¼″ – 2¼″
24″
4″ 4″
11¾″ – 11¾″
Manhole 10″ x 15″

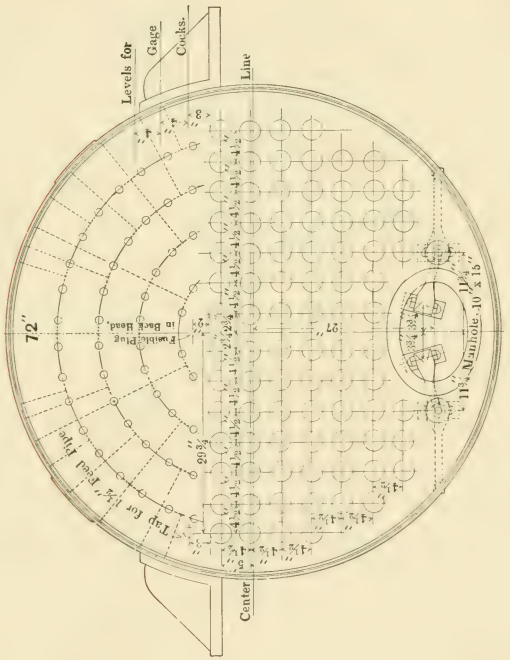
Diameter 66 in. Sixty-six 3½-in. Tubes.

Horizontal Fire Tubular Boilers, Continued.



Diameter 72 in. Seventy 4-in Tubes.

Horizontal Fire Tubular Boilers, Continued.



Diameter 72 in. Eighty-six 3½-in. Tubes.

Horizontal Fire Tubular Boilers, Continued.

"Hartford" Specifications for Boiler Steel.

Shells.—To be made of best Open Hearth Fire Box Steel, to have a tensile strength of not less than 55,000 lbs, nor more than 62,000 lbs. per square inch of section, with not less than 56% of ductility as indicated by contraction of area at point of fracture under test, and by an elongation of 25% in a length of 8 inches.

Heads.—To be made of best Open Hearth Flange Steel, 60,000 T. S. All plates, both of shell and heads, must be plainly stamped with name of maker, brand and tensile strength; brands so located that they may be seen on each plate after boiler is finished. Each shell plate must bear a coupon which shall be sheared off, finished up and tested by the maker of the boiler, at his own expense. Each coupon must fill the above requirements as to strength and ductility, and must also stand bending down double when cold, when red hot and after being heated red hot and quenched in cold water, without signs of fracture. All plates failing to pass these tests will be rejected. All tests and inspections of material shall be made at the place of manufacture prior to shipment.

Joints.—While Lap Joints are permissible for pressures of 100 lbs. and less, we never advocate the building of boilers with other than Triple Riveted Butt Joints and Inside and Outside Covering Straps. We therefore append table of data only for joints of that type:

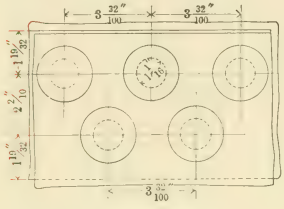
Triple Riveted Butt Joints.

(In inches.)

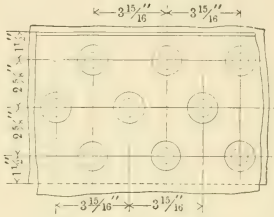
Thickness of Plate.	Diameter of Rivets.	Pitch of Rivets.	Width of Outside Butt Strap.	Width of Inside Butt Strap.	Thickness of Covering Straps.	Vertical or Transverse Pitch.	Edge of Butt Strap to Center of Rivets.	Pitch of Rivets Girth Seam.	Edge of Plate to Center of Rivets Girth Seam.	Strength of Joint.
1/4	1/2	2 1/2 x4 1/2	6 1/2	11 3/8	1/4	1 1/8	5/16	2 1/16	1 1/8	87 .5%
5/16	5/8	2 5/8 x4 5/16	6 3/4	12 3/8	5/16	1 1/2	11/32	2 1/16	1 1/8	86%
3/8	11/16	3 1/8x6 1/4	9 1/4	14	3/8	2 1/8	1 1/4	2 1/16	1 1/8	88%
11/32	11/16	3 1/8x6 1/4	9 1/4	14	3/8	2 1/8	1 1/4	2 1/8	1 5/32	88%
7/16	3/4	3 1/4 x6 1/2	9 3/4	14 1/4	7/16	2 1/8	1 5/32	2 1/8	1 5/32	87 .5%
13/32	3/4	3 1/4 x6 1/2	9 3/4	14 1/4	7/16	2 1/8	1 5/32	2 1/8	1 5/32	87 .5%
7/16	7/8	3 3/8x6 3/4	10 1/8	15 5/8	7/16	2 1/4	1 13/32	2 1/16	1 1/2	86%
15/32	7/8	3 1/2 x7	10 3/8	16	13/32	2 3/8	1 13/32	2 1/16	1 1/2	86%
1/2	15/16	3 3/4 x7 1/2	11	16 3/4	7/16	2 3/8	1 5/32	2 1/2	1 1/2	86 .6%

Horizontal Fire Tubular Boilers, Continued.

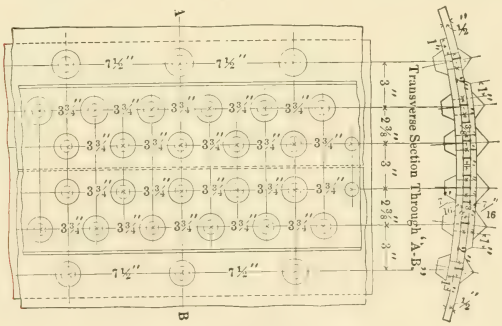
The following cuts illustrate the different types of joints and riveting :



Double Riveted Lap Joint.
(½″ plate ; $1\frac{1}{16}$″ holes ; 1″ rivets ; efficiency 68%)



Triple Riveted Lap Joint
(½″ plate ; 1″ holes ; $\frac{15}{16}$″ rivets ; efficiency 75%)



Triple Riveted Butt Joint.
(with inside and outside covering straps ; ½″ plate ; 1″ holes ; $\frac{15}{16}$″ rivets ; efficiency 86.6%)

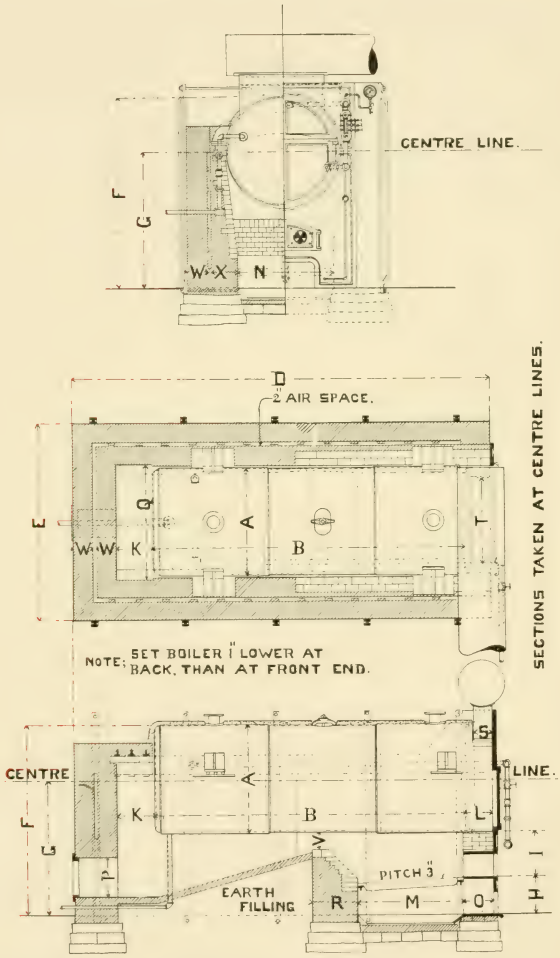
The above cuts illustrate only joints for ½″ plates ; from the table on the preceding page the proper dimensions for triple riveted butt joints for any thickness of plates can be found.

Table Showing Estimated Number of Brick Required to Set Boilers.

Horse Power. (Usual Rating.)	A	B	FLUSH FRONTS.			OVERHANGING FRONTS.		
			Number of fire brick.	Common Brick.		Number of fire brick.	Common Brick.	
				Number for one boiler.	Extra for each additional boiler.		Number for one boiler.	Extra for each additional boiler.
40	48	12-0	670	15300	7790	630	14570	7390
45	48	14-0	750	16000	8530	700	15290	8160
50	54	12-0	875	15450	8200	720	14510	7760
60	54	15-0	990	17600	9400	750	16700	8900
60	60	12-0	1050	16460	8600	900	15160	8100
70	60	14-0	1100	17780	9800	915	16680	9300
80	60	16-0	1140	19100	10200	950	18200	9700
90	66	15-0	1225	21170	11450	1025	19770	10850
100	66	16-0	1250	21900	11900	1050	20600	11300
125	66	18-0	1300	23500	12800	1350	22260	12200
125	72	16-0	1290	23000	12480	1330	21280	11880
150	72	18-0	1400	24000	13400	1400	23000	12800

For Diagrams corresponding to above lettered dimensions, see pages 502, 504 and 508.

Horizontal Fire Tubular Boilers, Continued.



Flush Fronts with Two Lugs.

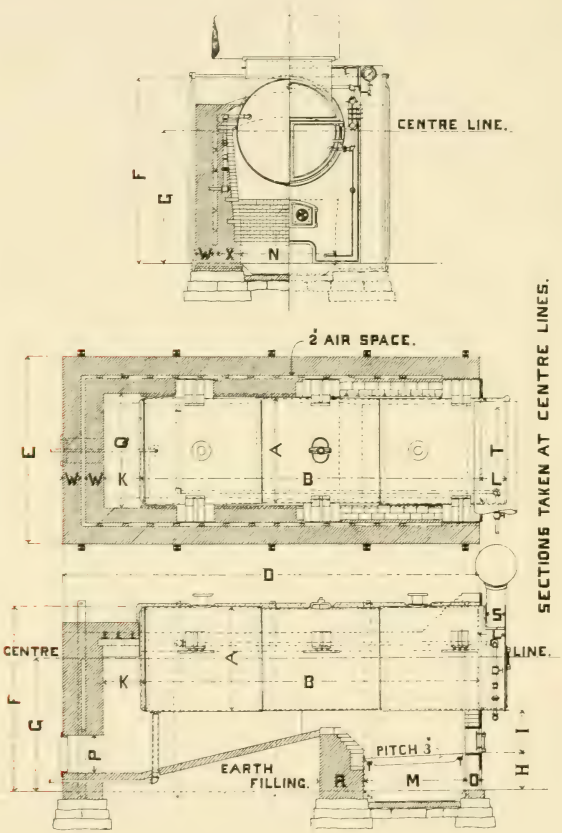
Dimension Table for Flush Fronts, with Lugs.

(In feet and inches.)

H. P. Usual Rating.	A	B	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	V	W	X
40	48	12-0	17-2	8-6	8-0	6-0	24	24	24	12	48	42	13½	24	54	28	8	36	8	12	16
45	48	14-0	16-2	8-6	8-0	6-0	24	24	24	12	48	42	13½	24	54	28	8	36	8	12	16
50	54	12-0	17-0	9-0	8-6	6-6	24	24	24	14	54	48	13½	24	60	28	9	42	9	12	16
60	54	15-0	20-0	9-0	8-6	6-6	24	24	24	14	54	48	13½	24	60	28	9	42	9	12	16
60	60	12-0	17-4	9-6	9-0	6-6	24	24	24	14	60	54	16	24	66	28	10	48	9	12	16
70	60	14-0	19-4	9-6	9-0	6-6	24	24	24	14	60	54	16	24	66	28	10	48	9	12	16
80	60	16-0	21-4	9-6	9-0	6-6	24	24	24	14	60	54	16	24	66	28	10	48	9	12	16
90	66	15-0	20-6	10-0	9-10	7-1	24	28	24	16	66	60	18	24	72	28	12	54	10	12	16
100	66	16-0	21-6	10-0	9-10	7-1	24	28	24	16	66	60	18	24	72	28	12	54	10	12	16
125	66	18-0	23-6	10-0	9-10	7-1	24	28	24	16	66	60	18	24	72	28	12	54	10	12	16
125	72	16-0	21-8	10-6	10-4	7-4	24	28	24	18	72	66	20	24	78	28	13	60	10	12	16
150	72	18-0	23-8	10-6	10-4	7-4	24	28	24	18	72	66	20	24	78	28	13	60	10	12	16

Note:—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purposes of installation.

Horizontal Fire Tubular Boilers, Continued.



Overhanging Fronts with (3) Lugs.

Note.—In the above cut rollers are shown under front lugs also. This is an error in the drawing; the front lugs should rest directly on the plates, same as on page 502.

Horizontal Fire Tubular Boilers, Continued.

Dimension Table for Overhanging Fronts.

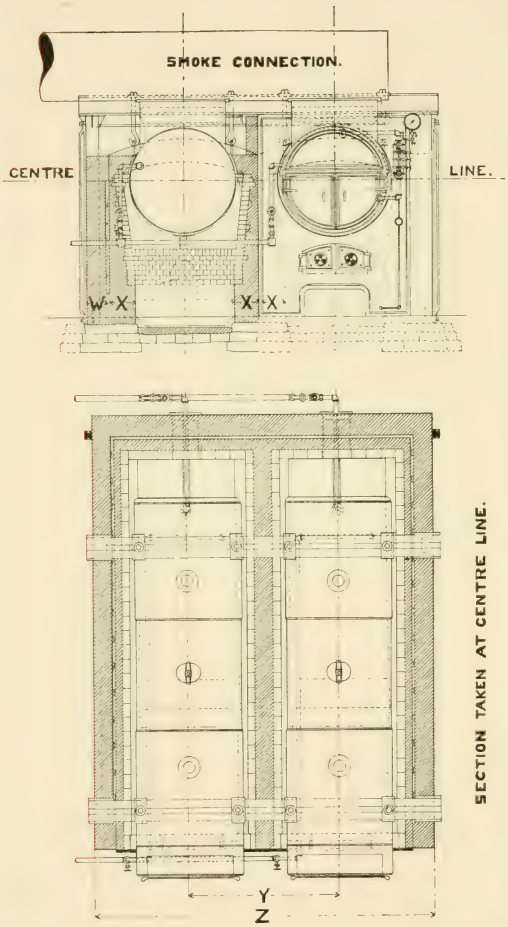
All dimensions same as those for "**Flush Fronts with Lugs,**" except the following :

(In feet and inches.)

Horse Power. (Usual Rating.)	A	B	Suspended or with Lugs.			
			D	O	S	T
40	48	12–0	16–2	9	8	36
45	48	14–0	18–2	9	8	36
50	54	12–0	16–2	9	9	42
60	54	15–0	19–2	9	9	42
60	60	12–0	16–2	9	10	48
70	60	14–0	18–2	9	10	48
80	60	16–0	20–2	9	10	48
90	66	15–0	19–2	9	12	54
100	66	16–0	20–2	9	12	54
125	66	18–0	22–2	9	12	54
125	72	16–0	20–2	9	13	60
150	72	18–0	22–2	9	13	60

Note.—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purposes of installation.

Horizontal Fire Tubular Boilers, Continued.



Boilers Set in Battery.

The smoke connection across the tops of the boilers should be shown increasing in size as it receives the connection from each succeeding boiler in the battery, instead of being of a uniform size as shown.

The above cut shows the overhanging type, suspended, which is probably the best practice: the dimensions apply, however, to each of the other types.

Horizontal Fire Tubular Boilers, Continued.

Dimension Table for Boilers Set in Battery.

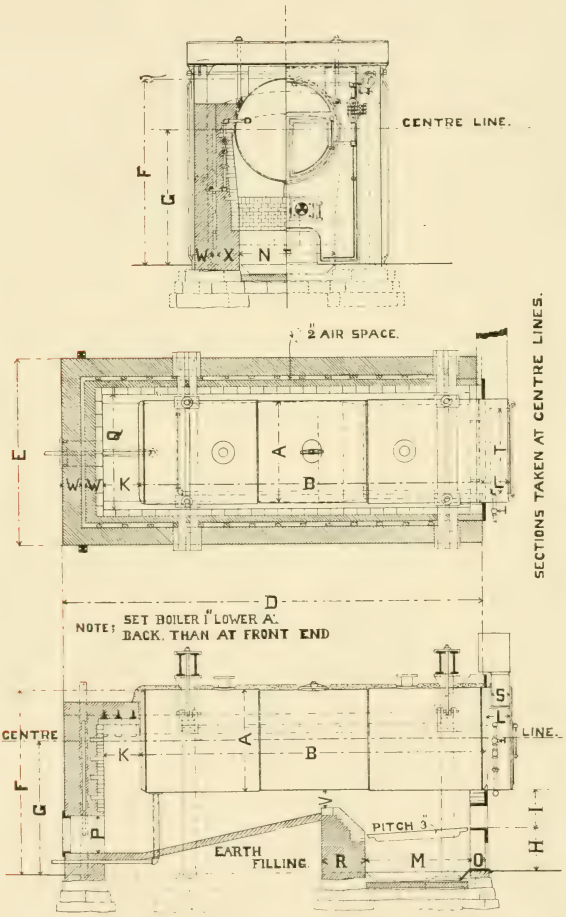
For boilers set in batteries of three, the dimension across the setting becomes of course Z + Y ; for four boilers it becomes Z + 2Y ; etc.

(In feet and inches.)

Horse Power. (Usual Rating.)	A (Diameter)	Y	Z
40	48	6–2	14–8
45	48	6–2	14–8
50	54	6–8	15–8
60	54	6–8	15–8
60	60	7–2	16–8
70	60	7–2	16–8
80	60	7–2	16–8
90	66	7–8	17–8
100	66	7–8	17–8
125	66	7–8	17–8
125	72	8–2	18–8
150	72	8–2	18–8

Note:—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purposes of installation.

Horizontal Fire Tubular Boilers, Continued.



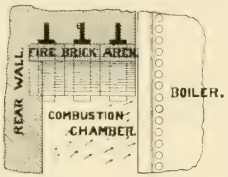
Overhanging Fronts, Suspended.

Horizontal Fire Tubular Boilers, Continued.

Notes on Setting.

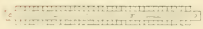
After making the excavation for the foundation, set the boiler in place and block it up 3″ or 4″ higher than it is to remain. Carry the side and end walls up to the proper height of the resting place for the lugs, in case the boiler is of that type, leaving headers in the wall so that the bridge and cross walls may be tied to them. Allow the work to stand a sufficient time for the walls to settle and harden, say six or eight days. When the walls are dry, let the boiler down until the lugs rest on the walls. Remove the blocking, and compiete the brick work. The space between the cross walls should be filled in with earth, and paved with brick. This keeps the heat near the boiler. Between the outside and inside wall there is an air space of 2″ which allows the inside wall to expand and contract without injury to the outside wall. The walls should have headers run from wall to wall every two feet but not tied together. Be careful in laying the fire brick that it may be repaired at any time without interfering with the main walls. In the fire brick lining, every sixth row should be headers all the way from front back to bridge wall. Asbestos or other suitable covering is necessary for the top of the boilers as well as the piping.

Horizontal Fire Tubular Boilers, Continued.



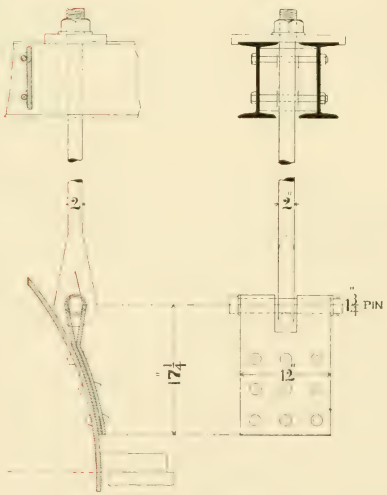
ARCH OVER BACK CONNECTION.

SIDE VIEW OF ARCH BAR.



TOP VIEW OF ARCH BAR.

Method of Supporting Back Arch.



Method of Suspension.

Horizontal Fire Tubular Boilers, Continued.

Rules for the Management and Care of Boilers.

(Under the supervision of the Hartford Steam Boiler Inspection and Insurance Company.)

1. Condition of Water.

The first duty of an Engineer, when he enters his boiler-room in the morning, is to ascertain how many gauges of water there are in his boilers. Never unbank nor replenish the fires until this is done. Accidents have occurred, and many boilers have been entirely ruined, from neglect of this precaution.

2. Low Water.

In case of low water, immediately cover the fires with ashes, or, if no ashes are at hand, use fresh coal, and close ash-pit doors. Don't turn on the feed under any circumstances, nor tamper with or open the safety-valve. Let the steam outlets remain as they are.

3. In Case of Framing.

Close throttle, and keep closed long enough to show true level of water. If that level is sufficiently high, feeding and blowing will usually suffice to correct the evil. In case of violent foaming, caused by dirty water, or change from salt to fresh, or vice versa, in addition to the action above stated, check draft, and cover fires with fresh coal.

4. Leaks.

When leaks are discovered they should be repaired as soon as possible.

5. Blowing Off.

Clean furnace and bridge wall of all coal and ashes. Allow brick work to cool down for two hours at least before opening blow. A pressure exceeding 20 lbs. should not be allowed when boilers are blown out. Blow out at least once

Horizontal Fire Tubular Boilers, Continued.

in two weeks. In case the feed becomes muddy, blow out six or eight inches every day. When surface blow-cocks are used, they should be often opened for a few moments at a time.

6. Filling Up the Boiler.

After blowing down allow the boiler to become cool before filling again. Cold water pumped into hot boilers is very injurious from sudden contraction.

7. Exterior of Boiler.

Care should be taken that no water comes in contact with the exterior of the boiler, either from leaky joints or otherwise.

8. Removing Deposit and Sediment.

In tubular boilers the hand-holes should be often opened, and all collections removed, and fireplates carefully cleaned. Also, when boilers are fed in front and blown off through the same pipe, the collection of mud or sediment in the rear end should be often removed.

9. Safety-Valves.

Raise the safety-valves cautiously and frequently, as they are liable to become fast in their seats, and useless for the purpose intended.

10. Safety-Valve and Pressure Gauge.

Should the gauge at any time indicate the limit of pressure allowed by this Company, see that the safety-valves are blowing off. In case of difference, notify the Company's inspector.

11. Gauge-Cocks, Glass Gauge.

Keep gauge-cocks clear, and in constant use. Glass gauges should not be relied on altogether.

12. Blisters.

When a blister appears there must be no delay in having

Horizontal Fire Tubular Boilers, Concluded.

it carefully examined, and trimmed or patched, as the case may euire.

13. Clean Sheets.

Particular care should be taken to keep sheets and parts of boilers exposed to the fire perfectly clean, also all tubes, flues, and connections well swept. This is particularly necessary where wood or soft coal is used for fuel.

14. General Care of Boilers and Connections.

Under all circumstances keep the gauges, cocks, etc., clean and in good order, and things generally in and about the engine and boiler-room in a neat condition.

Getting Up Steam.

In preparing to get up steam after boilers have been open or out of service, great care should be exercised in making the man and hand-hole joints. Safety-valve should then be opened and blocked open and the necessary supply of water run in or pumped into the boilers until it shows at second gauge in tubular and locomotive boilers; a higher level is advisable in vertical tubulars as a protection to the top ends of tubes. After this is done, fuel may be placed upon the grate, dampers opened, and fires started. If chimney or stack is cold and does not draw properly, burn some oily waste or light kindlings at the base. Start fires in ample time so it will not be necessary to urge them unduly. When steam issues from the safety-valve, lower it carefully to its seat and note pressure and behavior of steam gauge.

If there are other boilers in operation and stop-valves are to be opened to place boilers in connection with others on a steam pipe line, watch those recently fired up until pressure is up to that of the other boilers to which they are to be connected; and, when that pressure is attained, open the stop-valves very slowly and carefully.

Boiler Horse Power.

The Centennial Standard is defined to be the evaporation of 30 pounds of water per hour from a temperature of 100 degrees Fahrenheit into steam at 70 degrees gauge pressure. This is equivalent to the evaporation of 34½ pounds of water from and at 212 degrees Fahrenheit.

The term Horse Power, therefore, as applied to boilers, is understood to be a certain fixed number of pounds of water evaporated per hour, but the number varies according to the temperature of the feed water, the gauge pressure, and the barometric pressure.

The following table, for which I am indebted to "Power," shows the number of pounds per horse power per hour for different feed temperatures and gauge pressures:

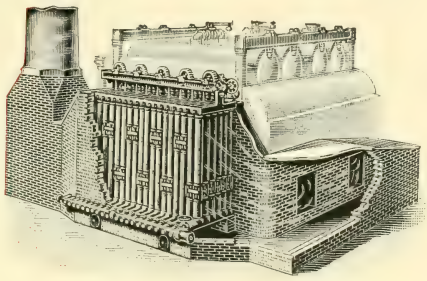
Table of Equivalent Evaporation.

Temperature of Feed.	Gauge Pressure, in Pounds.						
	80	100	120	140	160	180	200
40° F.	28.40	28.30	28.21	28.13	28.06	27.98	27.94
60°	28.89	28.79	28.69	28.61	28.54	28.47	28.41
80°	29.40	29.29	29.20	29.11	29.03	28.97	28.90
100°	29.93	29.81	29.71	29.63	29.55	29.48	29.41
120°	30.48	30.36	30.26	30.17	30.08	30.01	29.94
140°	31.05	30.92	30.82	30.72	30.64	30 57	30.50
160°	31.65	31.52	31.41	31.31	31.22	31.14	31.07
180°	32.26	32.13	32.02	31.91	31.82	31.74	31.66
200°	32.91	32.77	32.65	32.54	32.45	32.36	32.28

Another way of expressing a boiler horse power would be in thermal units. For instance, it requires 965.8 B. T. U. to generate one pound of steam from a feed temperature of 212 degrees of dry steam at the same temperature. As the horse power is equal to 34.5 pounds of water from and at 212 degrees, per hour, we have therefore 965.8 x 34.5=33,320 B. T. U.

As an engine horse power is expressed as 33,000 foot pounds per minute, a boiler horse power may be approximately expressed as 33,000 B. T. U. per hour.

GREEN FUEL ECONOMIZERS.



There is probably no adjunct to a modern steam plant whose economical value is now more readily recognized than that known as the Economizer.

It is well known to everyone connected with the working of steam boilers that in all cases there is a large amount of surplus heat which escapes up the chimney.

This should not be allowed to go to waste, and can be used for heating feed water for the boilers, to furnish hot water for dye houses, etc.

Fuel Economizers are peculiarly adapted to steam plants of the larger sizes, not only because the cost of the economizer is relatively small compared to the cost of the whole plant, but also because of the high pressures usually carried in larger plants. It is a recognized fact that the most economical boilers are those which have the most rapid circulation, and to obtain this circulation the temperature of the escaping gases must leave the boilers considerably above the temperature of the steam. Therefore, as already stated, with high pressures Economizers are almost a necessity.

The economy effected with an Economizer varies from 10% to 20% of the total fuel consumed, according to the temperature of the gases escaping from the boilers. By means of such an apparatus the temperature is reduced on an average from 550 degrees Fahrenheit on the boiler end of the Economizer to 300 degrees Fahrenheit on the chimney end; while

Fuel Economizers, Continued.

the temperature of the feed water is increased on an average about 150 degrees, which is clear gain, since it is effected by heat which would otherwise be wasted.

As already intimated, in the smaller plants running non-condensing, it is questioned whether the Economizer is worth the expense of installation and the cost of operating the same, because the ordinary type of feed water heater should heat the water to a temperature of 212 degrees for such a plant.

On the other hand, plants of moderate and large sizes generally use high pressures and their engines are compound condensing; the best practice seems not to be in favor of putting feed water heaters on the engine exhaust, as the net gain effected by it is entirely too small: not that feed water heaters are not used in such a case, for they are, but they are generally considered as auxiliary heaters and receive the exhaust from the pumps, the condenser itself if it is steam driven, auxiliary engines, etc. Medium and large plants carrying high pressures, therefore, are the ideal conditions under which Economizers can be operated.

The advantages claimed for an Economizer may be summed up as follows:

Saving from 10 to 20 per cent. in fuel.

Heating the feed-water economically to high temperatures, considerably above what can be obtained by other means.

A great volume of water always in reserve at the evaporative point, ready for immediate delivery to the boilers.

Utilizing in a practical way heat from the escaping gases which otherwise goes to waste.

Prolonging the life of boilers by the high temperature of feed-water, preventing the usual expansion and contraction.

Considerable sediment in the feed-water being deposited in the Economizer (where it can be easily blown off) by reason of slow circulation and the high temperature obtained.

Increasing the boiler efficiency by adding to its heating surface.

Some mills are using the hot water generated in the Economizer for manufacturing purposes, in their dye houses, or wherever any large quantities of hot water are used. It has been demonstrated that it is more economical to heat the water in the Economizer than to use live steam to do it.

Fuel Economizers, Continued.

When the Economizer is installed for the purpose of heating water for manufacturing purposes, it is generally divided into two sections, the first half of the Economizer being used for heating feed-water, and the second half for manufacturing purposes. A number of mills where they do not require hot water for manufacturing purposes are using the Economizer for heating their mills in the winter time, and in the summer time take the whole of the Economizer for heating feed-water for their boilers.

Construction.

The Economizer consists of a series of sets of cast iron tubes about 4 inches in diameter and 9 feet in length, made in sections (of various widths) and connected by "top" and "bottom headers," these again being coupled by "top" and "bottom branch pipes" running lengthwise, one at the top and the other at the bottom, on opposite sides and outside the brick chamber which encloses the apparatus. The waste gases are led to the Economizer by the ordinary flue from the boilers to the chimney.

The feed-water is forced into the Economizer by the boiler pump or injector, at the lower branch pipe nearest the point of exit of gases, and emerges from the Economizer at the upper branch pipe nearest the point where the gases enter.

Each tube is provided with a geared scraper, which travels continuously up and down the tubes at a slow rate of speed, the object being to keep the external surface clean and free from soot, a non-conductor of heat.

The mechanism for working the scrapers is placed on the top of the Economizer, outside the chamber, and the motive power is supplied either by a belt from some convenient shaft or small independent engine or motor. The power required for operating the gearing, however, is very small.

The apparatus is fitted with blow-off and safety valves, and a space is provided at the bottom of the chamber for the collection of the soot, which is removed by the scrapers.

Fuel Economizers, Continued.

Tubes.—The tubes are made from a mixture of the best American pig, cast vertically in dry sand moulds, and are guaranteed to be of equal thickness and free from blow-holes throughout. Before leaving the works tubes are tested up to a pressure of 350 pounds on the square inch.

Lids.—The lids to each tube are turned conical with a taper joint made metal to metal. The internal lid for high pressures has the large diameter inside the header, so that the pressure of water is all the time tending to tighten it. The external lid for ordinary pressures is held in place by a bolt and cross-bar, and is used for low pressures.

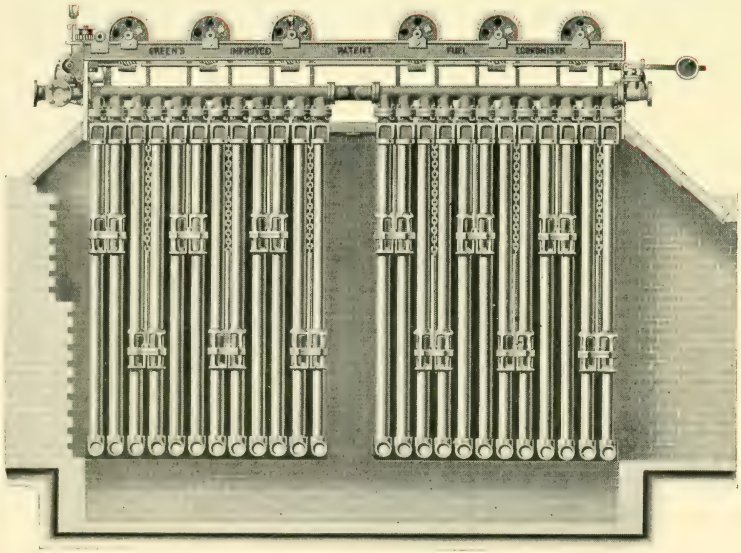
Headers.—Equal care is taken in the construction of headers. The joints of the tubes and headers are all conical, turned and bored metal to metal and forced together by powerful hydraulic pressing machinery expressly designed for the purpose.

Reversing Gear.—The gearing for operating and reversing the scrapers is simple and effective, and is worked by belt, link chain or rope drive. It is fitted with an improved clutch-box and reversing lever with rolling weight, which never fails to reverse at the right moment.

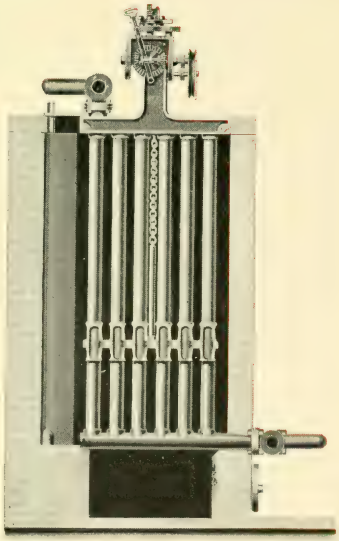
Access Branch Pipes.—These access pipes are manifolds with lids opposite each branch to facilitate cleaning. By removing the lids the bottom headers aud branch pipes can be thoroughly scraped out.

Sections of Tubes.—These sections are made four, six, eight, ten and twelve tubes wide, having a free flue area of 17, 29, 35, 40 and 46 square feet respectively.

The cuts on the following page make the preceding descriptions perfectly clear.



Longitudinal Section through Economizer Chamber.



Cross Section through
Economizer Chamber.

Atlanta, Ga., STUART W. CRAMER, Charlotte, N. C.

Fuel Economizers, Continued.

In estimating size of Economizer for a modern boiler plant where water heated by Economizer is to be used by boilers, allow 5 sq. ft. of heating surface in the Economizer per boiler horse power. Allow clear area between the tubes 10 to 15 per cent. more than the area in the main flue. Each tube and its connection holds about 1 cu. ft. of water and has 12 sq. ft. of external heating surface.

The following table shows average temperatures taken from the records of several different plants that have been in operation for some time.

Designation of Plants.	Number of Economizers.	Total Number of Tubes.	Temperature of Feed Water.	
			Entering Economizer.	Leaving Economizer.
No. 1.	3	1800	163	302
" 2.	2	384	160	240
" 3.	2	1600	145	285
" 4.	1	288	130	240
" 5.	1	320	130	217
" 6.	1	680	120	240
" 7.	1	288	116.9	212.5
" 8	2	896	102	195
" 9.	2	1264	178	288

Even more satisfactory results have been obtained from plants using Economizers and Mechanical Draft, as the following table will show :

Tests.	Gases Entering Economizer.	Gases Leaving Economizer.	Water Entering Economizer.	Water Leaving Economizer.	Gain in Temperature of Water.	Fuel Saving. Per Cent.
1	610	340	110	287	167	16.7
2	505	212	84	276	192	19.2
3	550	205	185	305	120	12.0
4	522	320	155	300	145	14.5
5	505	320	190	300	110	11.0
6	465	250	180	295	115	11.5
7	490	290	175	280	105	10.5
8	495	190	155	320	165	16.5
9	541	255	130	311	181	18.1

In every case the feed-water was partially heated by exhaust steam heaters or in hot wells by condensed steam from various sources

Table of Dimensions.

Number of Tubes.	Number of Tubes Wide.	Number of Rows.	Length Over Economizer.	Capacity in Pounds of Water.	External Heating Surface.
32	4	8	4′-10″	1984	384
48	4	12	7′- 3″	2976	576
64	4	16	9′- 8″	3968	768
80	4	20	12′- 1″	4960	960
96	4	24	14′- 6″	5952	1152
112	4	28	16′-11″	6944	1344
128	4	32	19′- 4″	7936	1536
144	4	36	21′- 9″	8928	1728
160	4	40	24′- 2″	9920	1920
176	4	44	26′- 7″	10912	2112
192	4	48	29′- 0″	11904	2304
208	4	52	31′- 5″	12896	2496
48	6	8	4′-10″	2976	576
72	6	12	7′- 3″	4464	864
96	6	16	9′- 8″	5952	1152
120	6	20	12′- 1″	7440	1440
144	6	24	14′- 6″	8928	1728
168	6	28	16′-11″	10416	2016
192	6	32	19′- 4″	11904	2304
216	6	36	21′- 9″	13392	2592
240	6	40	24′- 2″	14880	2880
264	6	44	26′- 7″	16368	3168
288	6	48	29′- 0″	17856	3456
312	6	52	31′- 5″	19344	3744
336	6	56	33′-10″	20832	4032
360	6	60	36′- 3″	22320	4320
96	8	12	7′- 3″	5952	1152
128	8	16	9′- 8″	7936	1536
160	8	20	12′- 1″	9920	1920
192	8	24	14′- 6″	11904	2304
224	8	28	16′-11″	13888	2688
256	8	32	19′- 4″	15872	3072
288	8	36	21′- 9″	17856	3456
320	8	40	24′- 2″	19840	3840
352	8	44	26′- 7″	21824	4224
384	8	48	29′- 0″	23808	4608
416	8	52	31′- 5″	25792	4992
448	8	56	33′-10″	27776	5376
480	8	60	36′- 3″	29760	5760
160	10	16	9′- 8″	9920	1920
200	10	20	12′- 1″	12400	2400
240	10	24	14′- 6″	14880	2800
280	10	28	16′-11″	17360	3360
320	10	32	19′- 4″	19840	3840
360	10	36	21′- 9″	22320	4320
400	10	40	24′- 2″	24800	4800
440	10	44	26′- 7″	27780	5280
480	10	48	29′- 0″	29780	5760
520	10	52	31′- 5″	32240	6240
560	10	56	33′-10″	34720	6720
600	10	60	36′- 3″	37200	7200
640	10	64	38′- 8″	39680	7680
680	10	68	41′- 1″	42160	8160
720	10	72	43′- 6″	44640	8640
760	10	76	45′-11″	47120	9120
800	10	80	48′- 4″	49600	9600

Fuel Economizers, Continued.

Table of Dimensions, Concluded.

Number of Tubes Wide.	Height Over		Dimensions Inside Walls.			Area Between Tubes.		
	Gearing.	Section.	Without Side Dampers.	With One Side Damper.	With Two Side Dampers.	Without Side Dampers.	With One Side Damper.	With Two Side Dampers.
4	13′–2¼″	10′–2¼″	3′–4″	4′–1″	4′–10″	16.6	23.85	31.10
6	"	"	4′–8″	5′–5″	6′– 2″	21.85	29.10	36.35
8	"	"	6′–0″	6′–9″	7′– 6″	27.00	34.25	41.5
10	"	"	7′–4″	8′–1″	8′–10″	32.25	39.50	46.75

Number of Brick, Size of Valves, Etc.

Number of Tubes.	Engine H. P. Required.	Valves.		Number of Bricks.					
				Above Foundations.			Foundations One Foot Deep.		Foundations 4 Feet Deep.
		Blow-off.	Safety.	Side Walls.	Inlet and Outlet.	Total.	Side Walls.	Inlet and Outlet.	
	E. H. P.	Inches.							
32	½	2	1½	1755	3532	5287	261	400	2644
48	½	2	1½	2632	"	6164	392	"	3168
64	½	2	1½	3509	"	7041	522	"	3688
80	½	2	1½	4387	"	7919	653	"	4212
96	1	2	1½	5264	"	8796	783	"	4732
112	1	2	1½	6141	"	9673	914	"	5256
128	1	2	1½	7018	"	10550	1044	"	5776
144	1	2½	2	7896	"	11428	1175	"	6300
160	2	2½	2	8773	"	12305	1305	"	6820
176	2	2½	2	9650	"	13182	1435	"	7340
192	2	2½	2	10527	"	14059	1566	"	7864
208	2	2½	2	11405	"	14937	1697	"	8388
48	½	2	1½	1755	4228	5983	261	489	3000
72	½	2	1½	2632	"	6860	392	"	3524
96	1	2	1½	3509	"	7737	522	"	4044
120	1	2	1½	4387	"	8615	653	"	4568
144	1	2½	2	5264	"	9492	783	"	5088
168	2	2½	2	6141	"	10369	914	"	5612
192	2	2½	2	7018	"	11246	1044	"	6132
216	2	2½	2	7896	"	12124	1175	"	6656
240	2	2½	2	8773	"	13001	1305	"	7176
264	2½	2½	2	9650	"	13878	1435	"	7696
288	2½	2½	2	10527	"	14755	1566	"	8220
312	2½	2½	2	11405	"	15633	1697	"	8744
336	2½	2½	2	12282	"	16510	1827	"	9264
360	3	3	2½	13159	"	17387	1961	"	9800

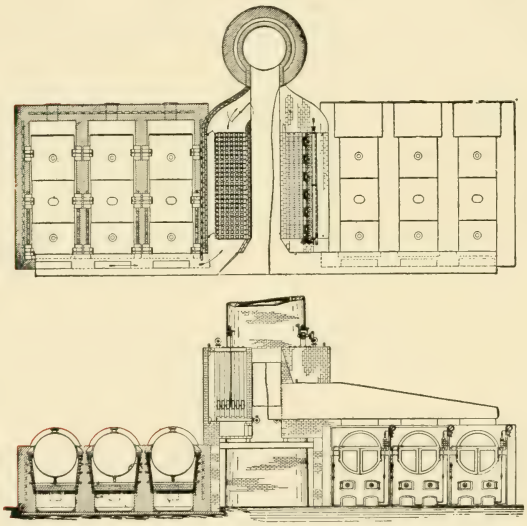
Fuel Economizers, Continued.

Number of Brick, Size of Valves, Etc., Concluded.

Number of Tubes.	Engine H. P. Required.	Valves.		Number of Bricks.					
				Above Foundations.			Foundations One Foot Deep.		Foundations 4 Feet Deep.
		Blow-off.	Safety.	Side Walls.	Inlet and Outlet.	Total.	Side Walls.	Inlet and Outlet.	
	E. H. P.	Inches.							
96	1	2	1½	2632	5403	8035	392	586	3912
128	1	2	1½	3509	"	8912	522	"	4432
160	2	2½	2	4387	"	9790	653	"	4956
192	2	2½	2	5264	"	10667	783	"	5476
224	2	2½	2	6141	"	11544	914	"	6000
256	2	2½	2	7018	"	12421	1044	"	6520
288	2½	2½	2	7896	"	13299	1175	"	7044
320	2½	2½	2	8773	"	14176	1305	"	7564
352	2½	3	2½	9650	"	15053	1435	"	8084
384	2½	3	2½	10527	"	15930	1566	"	8606
416	2½	3	2½	11405	"	16808	1697	"	9132
448	3	3	2½	12282	"	17685	1827	"	9652
480	3	3	2½	13159	"	18562	1961	"	10188
160	2	2½	2	3509	6720	10229	522	681	4812
200	2	2½	2	4387	"	11107	653	"	5336
240	2	2½	2	5264	"	11984	783	"	5856
280	2½	2½	2	6141	"	12861	914	"	6380
320	2½	3	2½	7018	"	13738	1044	"	6900
360	2½	3	2½	7896	"	14616	1175	"	7424
400	2½	3	2½	8773	"	15493	1305	"	7944
440	2½	3	2½	9650	"	16470	1435	"	8464
480	2½	3	2½	10527	"	17247	1566	"	8988
520	3	3	2½	11405	"	18125	1697	"	9512
560	3	4	3	12282	"	19002	1827	"	10032
600	3	4	3	13159	"	19879	1961	"	10568
640	3	4	3	14036	"	20756	2088	"	11076
680	3	4	3	14914	"	21634	2218	"	11596
720	4½	4	3	15791	"	22511	2349	"	12120
760	4½	4	3	16668	"	23388	2480	"	12644
800	5	4	3	17545	"	24265	2610	"	13164

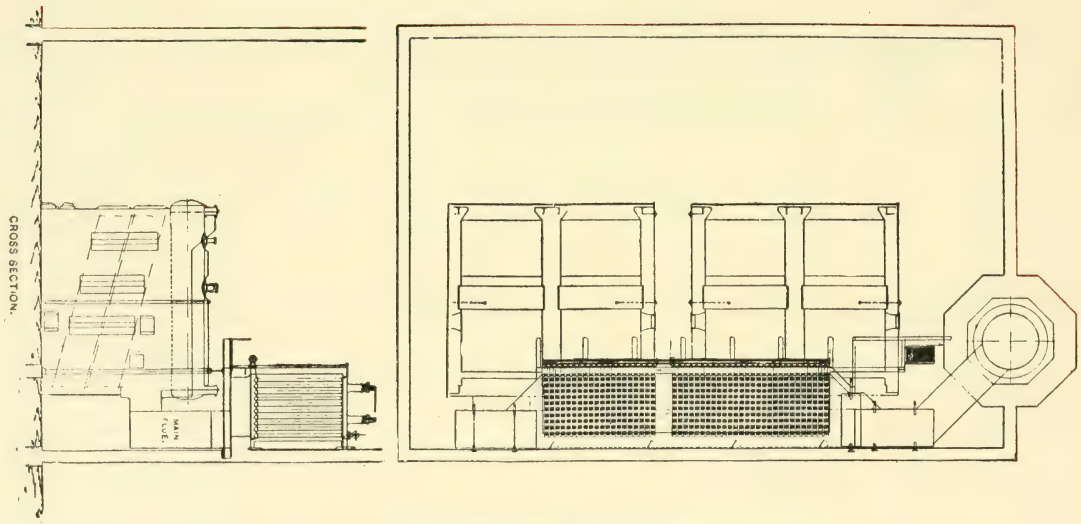
Fuel Economizers, Continued.

The following diagrams showing Economizers installed under different conditions will give a clear idea of their application, and suggest the proper arrangement for any particular case in hand :



900 Horse Power of Economizers.

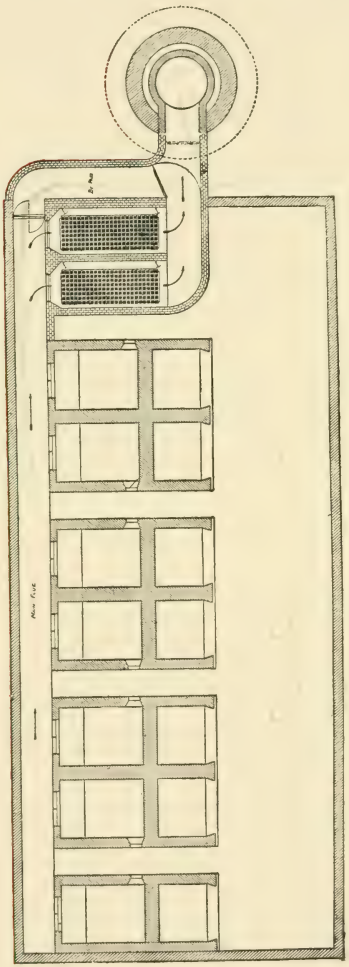
(As installed in connection with six 150 H. P. of Return Fire Tubular Boilers.)



1,000 Horse Power of Economizers.

(As installed in connection with two batteries of two 250 H. P. Babcock and Wilcox Water Tube Boilers.)

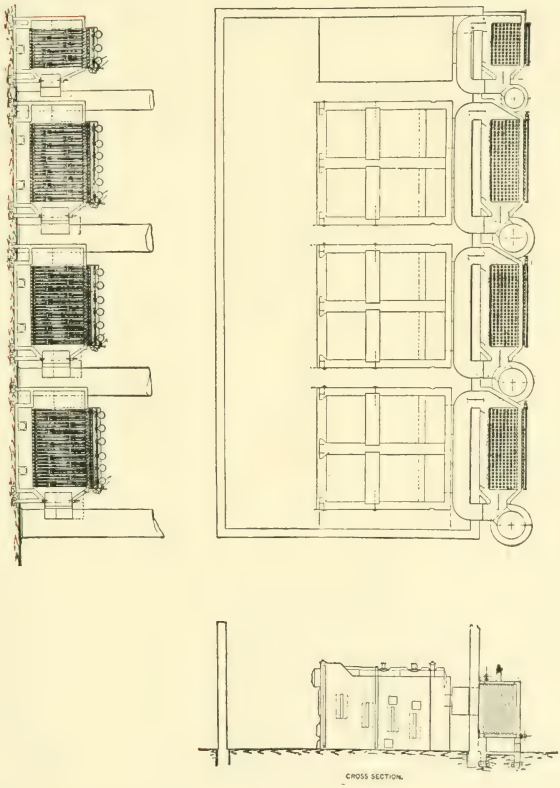
Fuel Economizers, Continued.



1,000 Horse Power of Economizers.

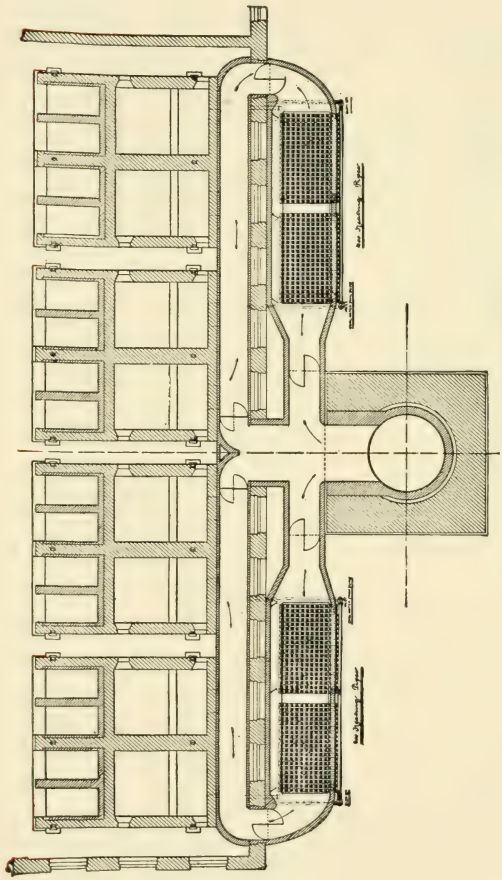
(As installed in connection with 1400 H. P. of B. and W. Water Tube Boilers—one battery of 400 H. P. in Boilers lying idle.

Fuel Economizers, Continued.



The above shows the same outfit as on the preceding page, but differently arranged, where it was considered best to use four iron stacks instead of one brick stack.

Fuel Economizers, Concluded.



2,000 Horse Power of Economizers.

(As installed with B. & W. Boilers and a Brick Stack.)

FUEL OIL APPARATUS.

Fuel Oil and other similar hydro-carbons must pass into a gaseous state before being burned. If immediately upon assuming the gaseous state they are mixed with a large quantity of air they are completely burned with a transparent blue flame producing carbonic acid and steam. When raised to a red heat before receiving a sufficient quantity of air for complete combustion, carbon is disengaged in a fine powder and the higher the temperature the greater is the proportion thus disengaged.

If this carbon is cooled below the temperature of ignition before coming in contact with oxygen it constitutes while floating in the gas smoke, and when deposited on solid bodies soot.

If the carbon is maintained at the temperature of ignition and supplied with oxygen sufficient for its combustion ; it burns while floating in the inflammable gas and forms red, yellow or white flame. The flame from fuel is the larger the more slowly its combustion is effected.

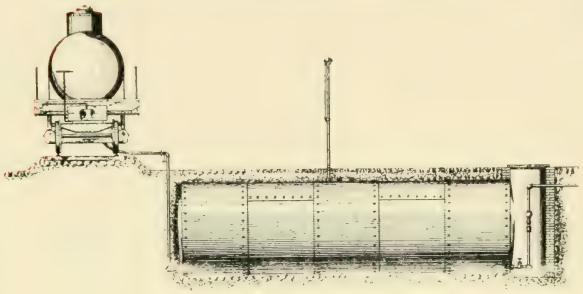
Oil Fuel as a Commercial Proposition.

In the following table showing the relative commercial values of coal and oil for fuel purposes, the coal considered is of the Pratt. Alabama, or Pittsburg coal, as sold in the New Orleans market.

Coal. Price per Ton 2,000 lbs.	Oil. Price per Bbl.
5.00	1.40
4.75	1.34
4.50	1.27
4.25	1.20
4.00	1.12
3.75	1.05
3.50	.99
3.25	.91
3.00	.84
2.75	.77
2.50	.70
2.25	.63
2.00	.56
1.75	.49
1.50	.42
1.25	.35
1.00	.28

A well designed water tube boiler will give an evaporation of ten pounds from and at 212 degrees, in the hands of a good fireman; the average boiler in ordinary service, however, will not show better results than eight pounds. With Beaumont oil having 19,000 B. T. U. per pound, an evaporation of fourteen pounds is readily obtained. Therefore, for every pound of coal, eight-fourteenths, or .571 will be required as an equivalent. A barrel of Beaumont oil weighs 318 pounds; consequently, one ton (2,000) of coal is equivalent to about 3.55 barrels of oil. This table does not show any cost for labor in firing and removal of ashes, both of which should be added to the oil side of the proposition.

Fuel Oil Apparatus, Continued.



Oil Storage and Handling.

It is better to consult the insurance companies with whom this insurance will be placed on this point; but briefly the custom is as follows:

Try to locate the plant so oil can be brought to it in tank cars which can be discharged directly into the storage tank through a piece of oil hose with suitable couplings. The tanks should be fitted with man holes, vent pipes, floats, etc., all as per insurance requirements.

If the storage tank cannot be located wholly below the ground level, its top should, if possible, not extend above the level of the burners.

Table of Standard Sizes of Tanks.

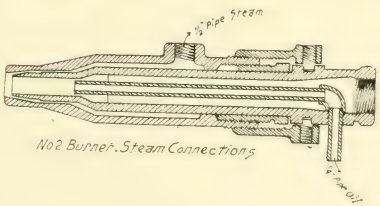
Dimensions.		Capacity.		Weight.
Diameter.	Length.	Gallons.	Barrels.	
6′	21′- 5″	4529	107	4441
6′	25′- 8″	5428	130	5232
6′	29′-11″	6345	151	5945
7′	21′- 5″	6165	147	5334
7′	25′- 8″	7388	175	6127
7′	29′-11″	8636	203	6986
8′	21′- 5″	8052	181	6250
8′	25′- 8″	9650	229	7204
8′	29′-11″	11240	266	8158
9′	21′- 5″	10192	240	7213
9′	25′- 8″	12214	291	8290
9′	29′-11″	14236	338	9367
10′	21′- 5″	12258	292	8092
10′	25′- 8″	15079	357	9280
10′	29′-11″	17576	417	10466

Fuel Oil Apparatus, Continued.

Apparatus.

Since Fuel Oil must be converted into a gas before combustion, it follows that it should be introduced into the furnace in as finely divided condition as practicable, in other words "atomized." The atomization is purely a mechanical process and the atomizer more commonly called "burner," which accomplishes the result the most effectually as regards mechanical division; and efficiently, as regards cost of operation is the best burner.

All of the burners on the market use either compressed air or steam in the shape of a jet for blowing the oil into the furnace. The form of burner, method of mixing the oil and atomizing agent, the adjustment of the steam and oil valves are numerous, ranging from the simple home-made device consisting of ordinary pipe and fittings to the highly scientific and ornamental productions which, while pleasing to the eye, are a sore trial to the temper of the user. Steam is almost universally used with burners for steam boilers on land as the use of air necessitates the installation of an air compresser.



The **Reid Burner** is one of the most successful types that have so far been developed; these are varied according to requirements. The above cuts illustrate that best adapted for use under boilers in cotton mills.

Fuel Oil Apparatus, Continued.

On account of insurance regulations prohibiting gravity supplies, it is necessary to have **at least one pump.** The function of the pump is to deliver the requisite quantity of oil at a uniform pressure, although at a varying rate, depending upon the demands of the boiler. The type of pump that fulfills the requirements of this service is a duplex pump automatically controlled.

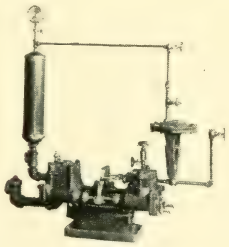
Assuming an evaporation of 14 lbs. of water per lb. of oil as a basis it will require about ½ gallon of oil per minute per 100 boiler horse power.

The following table, therefore, gives sizes of pumps suitable for this class of work and their capacities. It is recommended, however, to use one of the complete pumping outfits specially gotten up for this purpose as shown on the next page.

Size of Pump.	Piston Speed Ft. per Minute.	Capacity of Pump.	
		In Gallons per Minute.	In Boiler Horse Power.
2 x 1⅛ x 2¾	12	1	200
3 x 1¾ x 3	16	2½	500
3 x 2 x 3	16	5	1000
3 x 2¾ x 3	16	10	2000
4½ x 2¾ x 4	20	12½	2500
4½ x 3¾ x 4	20	22½	4500

Fuel Oil Apparatus, Continued.

The Number One apparatus consists of one Worthington Duplex Pump, fitted with bed plate and bracket, automatic pressure regulator, suction strainer, air chamber with gas valve for relieving air chamber of excessive accumulation of gas.



No. 1—Pumping Apparatus.

The Number Two apparatus is similar to Number One, except that there are two pumps cross connected.

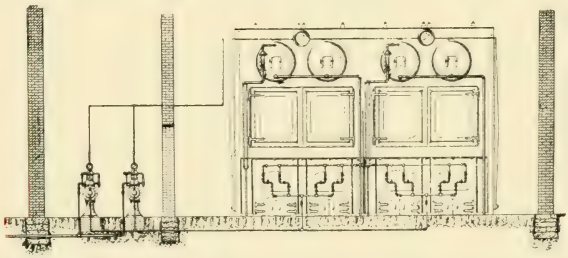
The above cut makes clear the types of pumping apparatus used. With them a special strainer should be used to keep out of the burners the impurities in the oil. The valve for regulating the supply of oil should be of the needle point variety.

The above data has been furnished us by **Mr. A. M. Lockett**, of New Orleans, La.

Fuel Oil Apparatus, Concluded.

The **Rockwell Engineering Company** have also done considerable work in this line, and the following cut illustrating one of their installations, will be found interesting and instructive.

This may be taken as a fair illustration of the necessary appliances and the method of delivering and burning fuel oil under boilers. Different conditions of location will, of course, necessitate different arrangement of appliances, but



the principle of delivery, storage and pumping should remain the same as far as possible.

The pumping system should be placed in the pump room, engine room or other convenient location, not in the boiler room, and the oil delivery pipe carried from it along the front of the boilers with a branch to each boiler. All oil lines should be laid below ground if possible. If not, they should be well secured and protected. All steam pipes should be well covered.

MECHANICAL STOKERS.

Mechanical stokers and patent furnaces are divided, by reason of the principle upon which they operate, into two classes: those "**overfeeding**" the coal, and those "**underfeeding**" the coal. The practicability of any stoker depends upon its efficiency and cost of maintenance. In both of these qualities, mechanical stokers have been found singularly lacking in Southern mills where their use has been attempted. For large central stations in cities, using special coals carefully broken and screened to size, they are unquestionably satisfactory and a good thing to put in. For Southern cotton mills, however, under the conditions that ordinarily exist, we advise against their use.

NOTE.—See page 959 Appendix to this Volume.

FUEL HANDLING APPARATUS.

Industrial Railways.

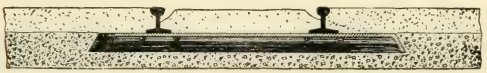
As applied to cotton mills, industrial railways are little used for anything except fuel and ash handling. Of course, the simplest fuel handling device for a steam plant would obviously consist of small cars traveling upon a narrow gauge track in front of the boilers, and to and from the coal chute.

Track.—For this work we would recommend a standard gauge of twenty inches from inside to inside of rail heads. The straight track can be made up either of cast iron lengths of up to six feet, or of standard T-rails riveted to steel cupped ties twenty-four inches on centers, or spiked to wooden ties.

These tracks can be bought complete, including switches, curves, turn tables, and even iron scale platforms.

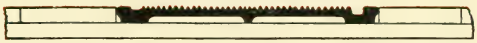
The following cuts illustrate different styles and kinds of track :

Section showing track made with flat ties and filled in between the rails with concrete.



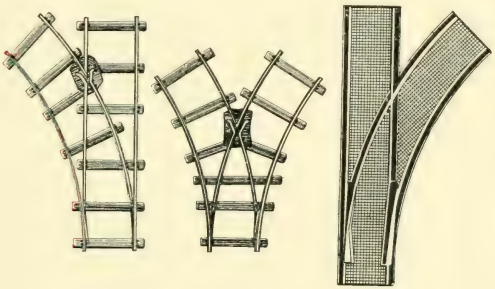
Standard track in made up section with cup tie buried in cement.

Section showing cast plate track laid in concrete, joined up with cast plate tile. This arrangement enables the finest construction for boiler room floor yet introduced, and will not buckle, warp or wear smooth or slippery.



Section showing cast plate track laid on wood floor.

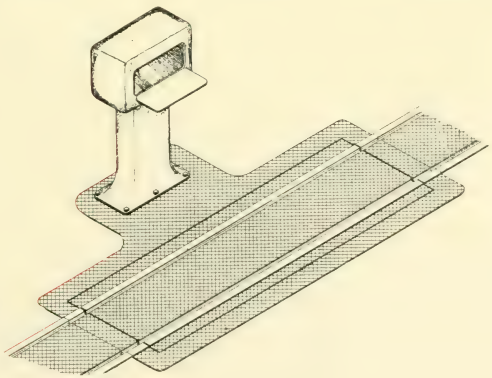
Section of cast plate between stone blocks on concrete or dirt foundation.



Left hand T-rail switch.

Two-way T-rail switch.

Right hand cast plate switch.



Iron Platform Scale, in connection with cast plate track.

Fuel Handling Apparatus, Continued.

Cars.—It should be especially noted that the cars must pass around a short radius curve as easily as on straight track, if the system is to be satisfactory. They should be equipped with roller bearings made of hard steel set in steel shells, with self-lubricating device, all fully protected from dust, dirt and grit. It is desirable also to have them equipped with self-equalizing springs, on which the load is to rest equally at all times, whether on straight or curved track.

Cars made with the tipping bodies are so arranged that the body of the car is kept under perfect control while the load is being dumped, and is easily and quickly adjusted.

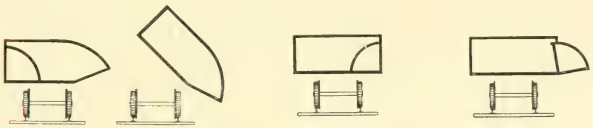
All rivet heads are counter sunk on the inside of the car body, thus preventing any obstructions or catching of the shovel.

The coal is shoveled direct from the car into the furnace, thus always maintaining a clean boiler room floor. The car should stand about seven or eight feet from the face of the furnace, which gives sufficient space for a man to stand between the furnace and the car while shoveling coal into the furnace. Should it be necessary to bring the car close to the furnace, it usually cramps the space which the workman uses for drawing ashes.

The bottom of the car is about the same height as the furnace door, which is a convenient height for shoveling the coal directly from the car into the furnace.

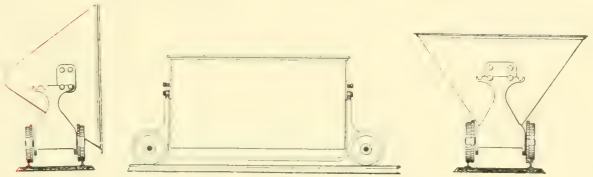
Fuel Handling Apparatus, Continued.

The following styles of cars and dimensions will be found to cover most of the conditions that will arise:



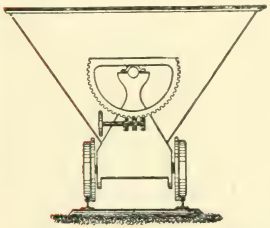
(Adapted for Coal Charging Cars.)

Coal capacity	1 ton.
Length over all in inches	92 inches.
Width over all in inches	43 inches.
Height of the top of the car	35 inches.
Height of the bottom	16 inches.
Scale platform, length	60 inches.
Turntable, diameter	54 inches.



(Adapted for Ash Handling.)

Capacity of car slightly heaped in cubic feet	13	18	22	30	40
Capacity, level full, cubic feet	12	15	18	25	33
Length of car over all in inches	68	70	72	75	80
Height of car above rail, over all, in inches	34	35	37	40	45
Width of car over all in inches	47	50	55	60	66
Diameter turntable required, inches	62	68	68	68	77
Scale platform required, in inches	60	96	96	96	96



Cars with worm gear attachment are very desirable where it is necessary to tip the car to shovel the material into it. The car can be adjusted to any angle in a tipping position, and at all times it is securely held.

Fuel Handling Apparatus, Continued.

The minimum weights of T-rails for various weights of loads are given in the following table, based upon the rule of one gross ton on one journal to ten pounds per yard weight of rail.

Number Tons.	Number Wheels.	Weight of Rails in lbs. per Yard.
4	4	10
5	4	16
7½	4	20
10	4	25
13	4	30

As already stated, T-rail track can be used and somewhat cheaper than cast iron track, but the cast iron plate track for boiler rooms laid in cement and permanently fixed is very much to be preferred; it will never wear smooth, it can be wheeled over without difficulty, it has a smooth surface with the floor, and it does not have any tendency to rust, splinter, or get out of alignment. The sections of straight cast plate track are made in lengths of one, two, three, four, five or six feet. For curves the twelve foot radius is the standard, though curves of eight and ten feet radius are also occasionally used. All the pieces are made interchangeable to form curves, switches, cross overs, and straight track, so that when assembled they will make complete a perfect track system.

Traction Data.

Gravity resistance in proportion to the grade is always 20 pounds per 2,000 pounds ton for each one foot rise in 100 feet. A grade of ½ per cent. will develop a resistance due to gravity of 10 pounds per ton; a 2 per cent. grade 40 pounds per ton; a 2½ per cent. grade 50 pounds, and 3 per cent. grade 60 pounds and so on.

Cars that are properly constructed with suitable oil boxes and bearings should not exceed 8 to 13 pounds frictional resistance per 2,000 pounds ton. With cars poorly constructed and with poor oiling arrangements for bearings from 20 to 40 pounds.

The total effort required to move cars is equal to the sum of the gravity and frictional resistances.

In actual practice it is found a workman can push the loaded car with one ton of coal easier than he can push a wheelbarrow with a load of 150 pounds.

Fuel Handling Apparatus, Continued.

Conveyor Systems.

In general, the subject of handling fuel and ashes has not heretofore been considered one of great importance to the average Southern cotton mill, because of the fact that the mills have generally been small and the steam generators have consisted of but very few units; furthermore, the spur track from the railroad is usually elevated at the boiler room end of the mill, so that the coal cars dump the fuel right where it can be most conveniently reached by the firemen, seldom more than one or two of whom are required.

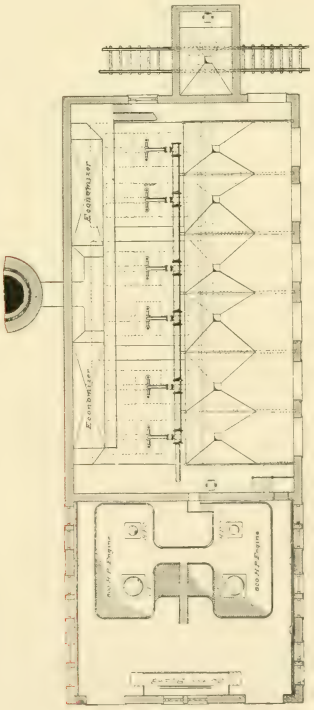
However, with the building of larger mills, the question of fuel handling has become relatively more important, quite a few of the larger cotton mill steam plants recently installed being of 1,000 to 2,000 horse-power capacity, and even 3,000 to 4,000 horse-power in notable instances.

Fuel handling rigs can generally be used to advantage where the number of boilers installed would require more than two firemen. Automatic stokers can also be used in connection therewith, but their utility is doubtful.

One of the best arrangements that has been brought to our notice for this purpose has been designed by C. R. Makepeace & Co., Mill Engineers, of Providence, R. I., for use in connection with one of their cotton mills; the cuts of it shown upon the following pages are sufficiently plain to require very little explanation.

Fuel Handling Apparatus, Continued.

Briefly, however, it will be seen to consist of a link belt conveyor system, which receives the coal from the cars through a hopper, carrying it overhead and dumping it in the storage bins in front of and above the boilers in the boiler room. The same conveyor system passes on over and down, returning beneath the boilers, and receives the ash from the furnaces to deposit it either in the ash bin or in any other desirable place. Of course, it is understood that the system works alternately, handling either the coal or the ash, as the circumstances require.



Fuel Handling Apparatus, Concluded.

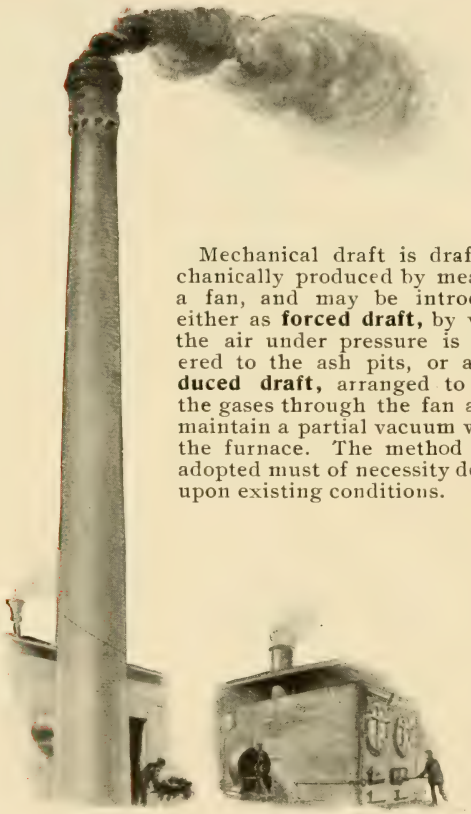
Longitudinal Section.

Cross Section.

The sections shown above are to be taken in conjunction with the plan on the opposite page. At the right of the longitudinal section it will be noticed that the coal car dumps into a hopper which delivers the coal into a breaker (crusher or cracker) to reduce it to a uniform size; from the breaker the coal is fed to the conveyor buckets by an automatic feeder termed a "filler."

In the best types, the line of conveyor buckets is moved by a special rig with pawl pushers instead of a sprocket wheel.

MECHANICAL DRAFT.



Mechanical draft is draft mechanically produced by means of a fan, and may be introduced either as **forced draft,** by which the air under pressure is delivered to the ash pits, or as **induced draft,** arranged to draw the gases through the fan and to maintain a partial vacuum within the furnace. The method to be adopted must of necessity depend upon existing conditions.

This is the size of the Smoke Stack.

This is the size of the Fan and Stack.

Required for the same boiler capacity.

Draft,

(See also Chapter on "Chimneys," Volume III.)

More or less confusion exists in the use of the term "draft" in boiler practice because of its double meaning. As usually employed, it refers to the difference in pressure between the external air and the gases as they leave the boiler; although, as related to the combustion of the fuel, it should properly apply to the difference between the under and over grate pressures. In either application it indicates the intensity or force of the draft, and is generally measured in inches of water by means of a draft gauge. The term "draft" is however, sometimes employed as a measure of the volume or weight of the gases passing through the fire. As the readings of a draft gauge give no direct indication of their volume, the quantity of air or gases must be determined by other means.

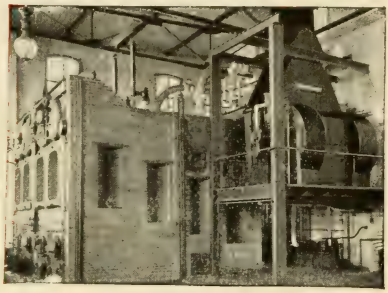
In the case of a chimney, the maximum intensity of draft exists only with the maximum temperature of the gases; but after the temperature reaches about 600° Fahr. their density decreases more rapidly than their velocity increases, so that the weight of air supplied is a maximum at about this temperature. As the draft is almost universally measured by the difference in pressure, expressed either in inches of water or in weight per unit of area, the term will be here employed as indicating the intensity or force with which it acts. This difference in pressure, whether it be the result of creating a plenum in the ashpit or a partial vacuum in the boiler furnace, is always necessary to produce the flow of air through the fuel whereby combustion is maintained. It is evident, therefore, that the draft or pressure difference and the velocity or air flow are independent.

Pressure in Inches of Water.

And Corresponding Pressure in Ounces, with Velocities of Air Due to Pressures at a Temperature of 50° F.

Pressure per Square Inch in Inches of Water.	Corresponding Pressure in Ounces per Square Inch.	Velocity Due to the Pressure in Feet per Minute.	Pressure per Square Inch in Inches of Water.	Corresponding Pressure in Ounces per Square Inch.	Velocity Due to the Pressure in Feet per Minute.
1/32	.01817	696.78	5/8	.36340	3118.38
1/16	.03634	987.66	3/4	.43608	3416.64
1/8	.07268	1393.75	7/8	.50870	3690.62
3/16	.10902	1707.00	1	.58140	3946.17
1/4	.14536	1971.30	1 1/4	.7267	4362.62
5/16	.18170	2204.16	1 1/2	.8721	4836.06
3/8	.21804	2414.70	1 3/4	1.0174	5224.98
1/2	.29072	2788.74	2	1.1628	5587.58

Mechanical Draft, Continued.



(Sturtevant.)

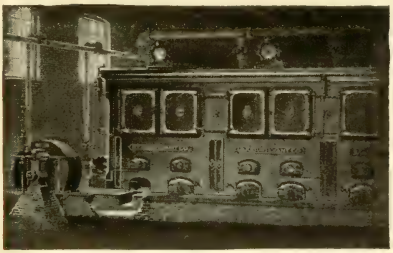
(Typical Induced Draft Apparatus, two fans, each with capacity of entire plant,—B. & W. Water Tubular Boilers.)

Volume and Density of Air at Various Temperatures.

Temperature. Degrees.	Volume of 1 lb. of Air at Atmospheric Pressure of 14.7 lbs. Cubic Feet.	Density or Weight of 1 Cubic foot of Air at 14.7 lbs. Pounds.	Temperature. Degrees.	Volume of 1 lb of Air at Atmospheric Pressure of 14.7 lbs. Cubic Feet.	Density or Weight of 1 Cubic Foot of Air at 14.7 lbs. Pounds.	Temperature. Degrees.	Volume of 1 lb of Air at Atmospheric Pressure of 14.7 lbs. Cubic Feet.	Density or Weight of 1 Cubic Foot of Air at 14.7 lbs. Pounds.
0	11.583	.086331	220	17.111	.058442	575	26.031	.038415
32	12.387	.080728	240	17.612	.056774	600	26.659	.03751
40	12.586	.079439	260	18.116	.0552	650	27.915	.035822
50	12.84	.077884	280	18.621	.05371	700	29.171	.03428
62	13.141	.076097	300	19.121	.052297	750	30.428	.032865
70	13.342	.07495	320	19.624	.050959	800	31.684	.031561
80	13.593	.073565	340	20.126	.049686	850	32.941	030358
90	13.845	.07223	360	20.63	.048476	900	34.197	.029242
100	14.096	.070942	380	21.131	.047323	950	35.454	.028206
120	14.592	.0685	400	21.634	.046223	1000	36.811	.027241
140	15.1	.066221	425	22.262	.04492	1500	49.375	.020295
160	15.603	.064088	450	22.89	.043686	2000	61.94	.016172
180	16.106	.06209	475	23.518	.04252	2500	74.565	.013441
200	16.606	.06021	500	24.146	.041414	3000	87.13	.011449
210	16.86	.059313	525	24.775	.040364			
212	16.91	.059135	550	25.403	.039365			

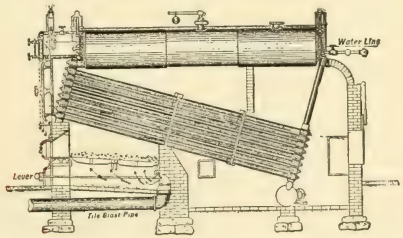
Forced Draft.

Forced draft is particularly applicable to old plants where increased capacity could otherwise be obtained only by adding boilers, increasing the height of the chimney, or building a new one. The air is discharged into the ashpit through openings in its sides or bottom. The air duct may be laid beneath the floor in front of the boilers, a hollow bridge wall may serve as a conduit, or a pipe may be carried overhead, with downward extending branches.



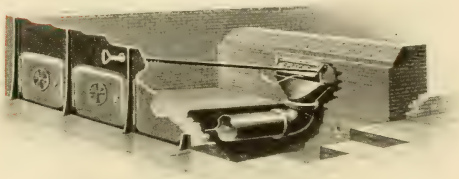
(Sturtevant.)

The above cut shows a typical forced draft plant, installed in connection with a battery of horizontal fire tubular boilers. The fan is so designed that the air may be discharged into an underground brick duct, extending along the front of the boilers, whence it passes through branch ducts to the individual dampers in the ashpits.



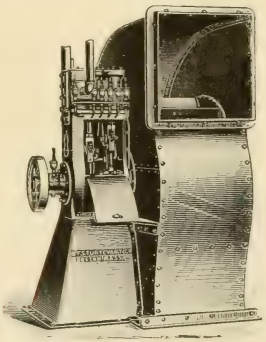
In a new plant, however, the bridge wall may be left hollow and utilized as an air duct, a special damper being employed, and operated from the front by means of a notched handle bar. The effect of both forms of damper is to spread the air evenly over the entire bottom of the ashpit, whence it rises in even volume and at low velocity.

Mechanical Draft, Continued.



Forced Draft Dampers.

(In position in bridge walls. Rectangular type for brick air flue, also round form for the tile duct.)



Forced Draft Steam Fan.

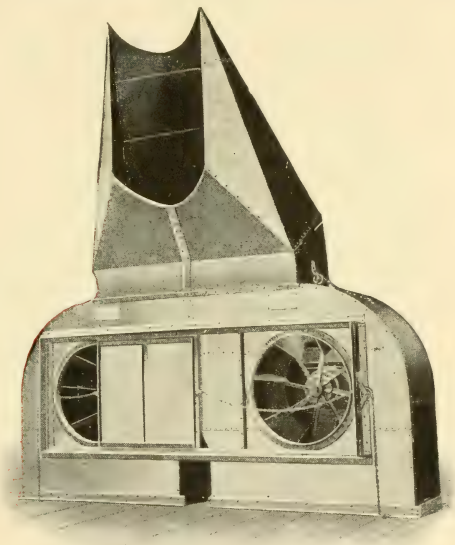
(Sturtevant.)

(With double upright engine, cylinders above shaft, full housing, top horizontal discharge fan.)

Mechanical Draft, Continued.

Induced Draft.

Induced draft has become the most common form of mechanical draft in new power plants. It is generally installed in conjunction with fuel economizers. For this class



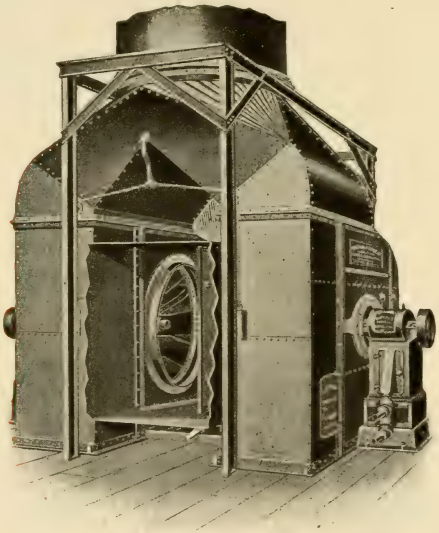
(Sturtevant.)

Induced Draft Fans.

of work duplex fans are recommended, the two being placed side by side, each equipped with a direct connected engine, and of sufficient capacity to do the work singly. The fans and engines are made with protected bearings, self-oiling and water jacketed, to stand the heat of the hot gases passing directly to them when the economizer is cut out for cleaning. The fans are steel plate, heavily braced with angle and "T"

Mechanical Draft, Continued.

irons, forming such a construction that the heat from the flue gases will cause no distortion by reason of expansion. The



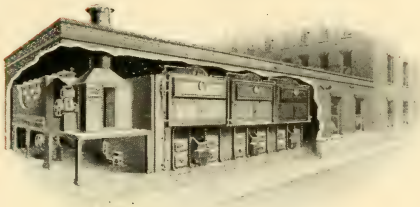
(**Buffalo.**)

(With double enclosed engines, connections to stack, supporting frame work, fan wheels overhung, water-cooled bearings.)

water cooling boxes to the bearings are made sufficient to withstand a flow of water at city pressure without leakage.

The foregoing illustrate only two of the many types of fans applicable to this class of work.

Mechanical Draft, Continued.



(**Buffalo.**)

The above cut represents the boiler room of a manufacturing plant that was formerly equipped with a brick stack. In overhauling and enlarging the plant, the brick stack was torn away, additional boilers were installed, with an induced draft outfit, economizers, etc.

Notes on Installations for Mechanical Draft.

Typical Features of Mechanical Draft.—Costs less than one third the cost of a chimney; lower grade fuel can be burned; permits of utilizing more of the heat in escaping gases without restricting combustion; decreases smoke; responds quickly to sudden demands for more steam; is independent of wind, weather, or temperature of gases; costs but little for operation, especially when fan engine exhaust is utilized; can be applied to old as well as new plants; and, finally, the steaming capacity of the boilers can be increased where the installation has outgrown the stack capacity.

Relative Cost of Operation.—The power required to drive a fan for mechanical draft varies, of course, according to local conditions; from one to two per cent. of boiler horse power developed would seem to be a fair average, under the best practice Or, estimating coal at $4 per ton, the fuel cost of operating the plant will figure out to be about three to six per cent. of the estimated cost of a chimney to take care of the same draft.

Mechanical Draft, Continued.

Size of Apparatus Required.

As already stated, the design of the apparatus required depends upon a number of local conditions, for which no set rules can apply. A general idea, however, can be obtained from the following tables, furnished through the courtesy of B. F. Sturtevant Company and the Buffalo Forge Company.

Buffalo Steel Plate Fans.

Table of capacities for forced or induced draft in boiler horse power.

Basis of Calculations.

Fine Cumberland or Pocahontas Coal.
5 lbs. coal per H. P.
18 lbs. air per lb. of coal.
Draft Pressure :— { I. D. one inch. / F. D. one oz.
Temperature of boiler room 62 degrees.
Temperature of flue gases 500–600 degrees.

(No Economizers.)

Size of Fan in Inches.	Width of Shell.	Diameter of Blast Wheel.	Width at Periphery.	Induced Draft.			Forced Draft.			Capacity in Boiler H. P.	
				Speed in Revs. per Min.	Capacity in cu. ft. per Min.	Brake H. P.	Speed in Revs. per Min.	Capacity in cu. ft. per Min.	Brake H. P.	Induced Draft.	Forced Draft.
50	18½	36	12½	.....		.....	547	5355	2.75	.....	270
60	22¼	43	16¾	528	8700	4.9	460	8330	3.5	216	415
70	26	50	19	460	11800	6.7	395	11260	4.8	294	560
80	29¾	57	21¼	400	15100	8.6	346	14480	6.1	375	725
90	33½	64	24	356	19150	10.8	310	18430	7.7	475	920
100	37½	71	27¾	320	24600	14.0	280	23740	9.9	615	1185
110	41	78	30	291	29260	16.5	253	27970	11.7	732	1395
120	44¾	85	33¾	267	38500	21.0	233	34400	14.4	895	1770
130	48½	92	36	247	41300	24.0	215	39600	16.6	1020	2000
140	52¾	99	39¼	229	48500	27.5	200	46400	19.5	1200	2320
150	56	106	42	214	55650	31.5	.....	.....	.....	1380	.....
160	59¾	113	45¼	201	64000	36.0	.....	.....	.....	1590	.....
170	63½	120	47½	190	71300	40.5	.....		.....	1772	.....
180	67¼	127	51¼	179	81200	46.0	.....	...	.....	2000	.....
190	71	134	55	169	92100	52.0	.....	.....	.....	2280	.....
200	74¾	141	58¾	161	103500	58.0	.....	.....	.. ..	2570	.....
210	78½	148	62	.....	.....	...	.....	.....	.....	... ...	.....
220	82¼	155	66	.....	.....	.....	.....	.....	...	.....	.....

Mechanical Draft, Continued.

Sturtevant Steel Plate Fans.

Table of capacities for forced or induced draft in boiler horse power.

Basis of Calculations.

Fine Cumberland or Pocahontas Coal.
4 lbs. coal per H. P.
300 cubic feet air per lb. of coal.
Draft Pressure :— { I. D. one inch. / F. D. one oz.
Temperature of air 60 degrees on forced draft.
Temperature of gases 600 degrees on induced draft.
(No Economizers.)

Size of Fan, in Inches.	Width of Shell.	Diameter of Blast Wheel.	Induced Draft.			Forced Draft.			Capacity in Boiler H. P.	
			Speed in Revolutions per Minute.	Capacity in cu. ft. per Minute.	Brake H. P.	Speed in Revolutions per Minute.	Capacity in cu. ft. per Minute.	Brake H. P.	Induced Draft.	Forced Draft.
50	15	30	738	4120	1.6	660	3690	2.3	100	180
60	18	36	617	7160	2.8	550	6400	4.0	180	320
70	21	42	528	9410	3.6	470	8420	5.1	230	420
80	24	48	464	12030	4.7	414	10800	6.6	300	540
90	28	54	411	16400	6.3	367	14700	8.9	400	735
100	32	60	369	19500	7.5	330	17400	10.8	500	870
110	36	66	337	25600	10.0	300	22900	14.1	650	1140
120	42	72	308	33900	13.0	275	30400	18.6	850	1500
130	42	78	284	35950	13.9	254	32200	20.0	900	1600
140	48	84	264	45400	17.5	235	40500	25.0	1100	2000
150	48	90	246	46900	18.1	220	42100	26.0	1175	2100
160	48	96	232	50100	19.1	207	45000	27.4	1250	2250
170	48	102	218	52100	20.0	194	46750	28.8	1300	2350
180	54	108	206	63700	24.6	183	57150	35.7	1575	2850
200	60	120	185	80500	31.0	165	72200	44.8	2000	3600
220	66	132	168	97000	37.4	150	87000	53.4	2400	
240	72	144	155	114500	44.0	138	103000	63.0	2800	
260	78	156	143	135500	52.0	127	123000	74.8	3350	
280	84	168	132	156300	60.0	118	140000	87.1	3900	

Mechanical Draft, Concluded.

The Effect of the Use of Economizers.—Without economizers the temperature of the gases under normal conditions ranges from 500 degrees Fahrenheit for a water tubular boiler to 550 degrees for a fire tubular boiler. When economizers are used, the temperature of the flue gases is reduced to 250 to 350 degrees.

The use of economizers affects the situation as follows:

The weight of the gases to be handled may be considered the same regardless of the temperature; the volume of a given weight of gases varies directly as the absolute temperature; therefore, the number of cubic feet to be handled by the fan will vary directly as the absolute temperature. So that, supposing the fan to be ample in capacity to handle the required amount of gases (at say 550 degrees) when the boilers are running without economizers, the proper size fan for the same horse power with economizers and gases at say 250 degrees would be expressed by the following fraction:

$$\frac{250 + 461}{500 + 461} = \frac{711}{961} \text{ or } 0.74, \text{ approximately.}$$

The intensity of the draft also figures in the calculation somewhat. In order to overcome the resistance of the economizers, it is customary to figure on 1¼″ draft at the fan outlet instead of 1″. This difference in intensity, however, is taken care of by increasing or reducing the speed according to whether the economizers are in use or not.

The following table giving a series of tests of induced draft plants with economizer, shows results that can easily be obtained from any well designed plant.

Tests.	Gases Entering Economizer.	Gases Leaving Economizer.	Water Entering Economizer.	Water Leaving Economizer.	Gain in Temperature of Water.	Fuel Saving. Per Cent.
10	610	340	110	287	167	16.7
11	505	212	84	276	192	19.2
12	550	205	185	305	120	12 0
13	522	320	155	300	145	14.5
14	505	320	190	300	110	11.0
15	465	250	180	295	115	11.5
16	490	290	175	280	105	10 5
17	495	190	155	320	165	16 5
18	541	255	130	311	181	18.1

Note.—Feed water was partially heated by exhaust from auxiliaries, or taken from hot well.

Open Feed Water Heaters.

Webster "Vacuum" Feed Water Heater and Purifier.

This heater is of the "open" type, but is not to be confused in principle with the ordinary type of heater, through which all the engine exhaust is passed. The Webster Heaters receive only the amount of steam required to heat the feed water, and therefore are not a "thoroughfare," so to speak, for using the exhaust steam from the engine,—only sufficient steam required to heat the feed water being passed through the heater.

Not being a "thoroughfare" (the steam supply to the heater being taken through a branch from the main exhaust pipe), it follows that most of the cylinder oil used for lubricating the engine is not to be considered; the small amount of oil actually present in the exhaust steam before it is taken into the heater is effectually separated and removed. This branch connection and the principle upon which the heater operates also relieve the engine of back pressure.

The term "Vacuum" is ordinarily given to this heater because, being sealed from the atmosphere, the heater will draw or absorb through the exhaust pipe the required amount of steam to heat the feed water. Should the quantity of steam thus furnished the heater at times be insufficient to maintain the highest temperature, a partial vacuum will result, which is dependent on the temperature of the feed water and the distance the surface of the water in the heater is above the suction valve of the boiler feed pump.

The principal claims made for the Webster heaters are as follows:

(1). A maximum attainable temperature is imparted to the feed water, which is guaranteed to be within two to four degrees of the temperature of the steam.

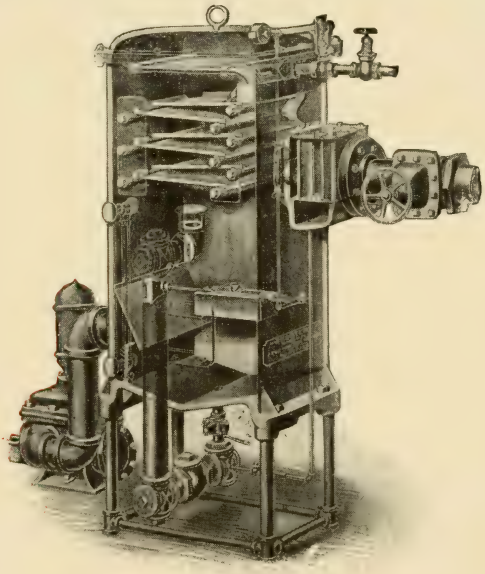
(2). This full heating effect is accomplished without back pressure on the engine.

(3). Owing to the steam coming into actual contact with the water, a minimum amount of steam is required to furnish a maximum amount of heat to the feed water.

(4). The cylinder oil present in the exhaust steam that goes to the heater is effectually separated and removed so that the water passing through the heater is at all times suitable for boiler use.

Webster Feed Water Heaters, Continued.

Standard Pattern, Class "A."—This class of heater is adapted to and recommended for power plants in which the quality of the feed water is suitable for boiler use. In addition to its regular service in heating and purifying the feed water, it is also arranged to receive through suitable inlets the condensation from the steam heating system and other available sources from whence the water thus saved is returned to the boilers. For water containing mud, lime, magnesia, etc., the Class "C" heater, in which a filter is combined in its construction, is recommended.



This standard Class "A" heater consists of a closed cast iron shell, or casing, with a removable cover, and a doubly inclined bottom, suitably provided with inlet pipes for exhaust steam and cold water respectively, the supply of the latter being automatically controlled by a balanced valve and open gravity sink attachment. All the cast iron plates of which the heater is composed are put together by a patent

rust joint, the special feature of which is the protection of the bolts joining the cast iron plates of which the shell is made up.

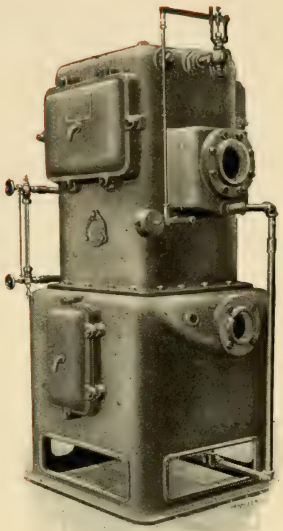
The heater is further provided with a Webster oil separator, properly drained, which effectually and completely removes the oil present in the exhaust steam before it enters the heater: this oil separator is made a part of the heater construction.

It is also provided with a sealed overflow, a bottom blow-off or drain connection, and outlet for the heated and purified water leading to the boiler feed pump, a gauge glass, and a combination vent and inlet air valve. The exhaust steam is admitted by a branch from the main exhaust pipe into the heater casing (which is sealed from the atmosphere), and there brought into direct contact with a series of oppositely inclined perforated copper trays, which are arranged to spread the water over an extended surface, and sub-divide its volume into fine particles, whereby a thorough absorption of the heat in the exhaust steam is effected. The water entering the heater, at one side close to the top, is discharged into a cast iron header or trough, from which it flows over the trays referred to. Being sprayed successively from one to the other of these trays, the water falls into the settling chamber heated to the highest possible temperature obtainable from the steam supply. The trays are fastened into the heaters by means of brass bolts, seen at the front, and can be readily removed by unbolting the cover.

An apron extending entirely across the lower part of the casing in front of the hot water outlet, the lower part of which is submerged, effectively prevents any scum or light impurities or oil from reaching the boiler.

The heavy mechanical solids, that can be separated by the temperature of the exhaust steam, are precipitated and arrested by the copper trays, upon which they accumulate, and also in the bottom of the settling chamber, by reason of the feed water storage being of sufficient volume to allow the water to remain in a quiescent state. This accumulation of sediment upon the bottom of the chamber can be drained off by the doubly inclined bottom, and is "washed out" through the blow off.

Owing to the saving of condensation by liquefying the exhaust steam used in the heating of the water, there is effected an economy in the amount of city or supplemental water required by the boilers of about 13%, depending upon the initial temperature of water supplied, which aside from its commercial value, is an important factor in the function of the heater to effect purification. It means that much less impure water with which to deal.



Class "E. C."

Webster Special "Star Vacuum" Feed Water Heater, Purifier and Filter.—As already noted, this class of heater has a filter combined with its construction, which makes it particularly adaptable to water containing mud, lime, magnesia, etc. For regular service in heating, purifying and filtering feed water, and when not used as a "receiver" for condensation from sundry sources, the heater is supplied with steam not above atmospheric pressure, thus avoiding back pressure on the engine, which is the condition imposed by closed heaters. Their construction, however, also prevents the loss of steam for ordinary operating pressure not exceeding one pound.

When used as a **Feed Water Heater, Purifier and Filter, and "Receiver for Condensation,"** the heater is furnished with a balanced valve or pressure attachment. This is the case when the heater is supplied with steam from an engine working against back pressure, or, for instance, with a gravity steam heating system, in which the exhaust steam is used for heating the mill. The function of the valve is to prevent the loss of steam when the operating pressure within the heater is greater than the usual water seal provided will allow (say about one pound).

Webster Feed Water Heaters, Concluded.

Table of Details and Dimensions.

(Dimensions in Inches.)

Class "A" Heater and Purifier.

Number of heater.	Rating of Heater in Horse Power.	Size of Pipes.			Height from Floor to Centre of			Over All Dimensions.		
		Exhaust Inlet.	Cold Water Inlet.	Hot Water Pump Outlet.	Exhaust Inlet.	Cold Water Inlet.	Hot Water Outlet.	Height Including Stand.	Length Including Separator.	Width Including Overflow.
0	50– 75	3	1	2	32½	40⅛	16½	46⅝	31⅛	20⅜
1	100–125	4	1	2½	35	44	18	50½	33¾	22⅛
1½	150–175	4	1	2½	37½	47¾	19½	55¼	35⅝	25⅞
2	200–250	4	1	3	42	54	21¼	62	37¾	28 3/16
3	300–350	5	1	4	47 3/4	61 1/16	25	69¼	41⅛	30¾
4	400–450	6	1¼	4	49 3/4	66½	27¼	75½	46 5/16	33 5/16
4½	450–475	7	1¾	4	50½	67½	29	75½	48 13/16	41 15/16
5	500–550	10	2	4	58⅜	80¾	27¼	88¾	55⅜	45
6	600–650	10	2	4	58¼	80¾	27¼	88¾	55⅜	45

Class "E. C." Heater, Purifier and Filter.

0	50– 75	3	1	2	40¼	50 3/4	19⅜	52¾	27¾	18½
1	100– 150	4	1	2½	45 3/4	58⅛	22⅛	60	32 3/4	22⅛
2	200– 250	4	1	3	47½	62⅛	24	64½	39	27⅜
3	300– 350	5	1	4	51⅝	70 3/4	28⅜	73⅛	41 3/4	31½
4	400– 450	6	1¼	4	60¼	78⅛	30¾	80 3/4	45¼	34½

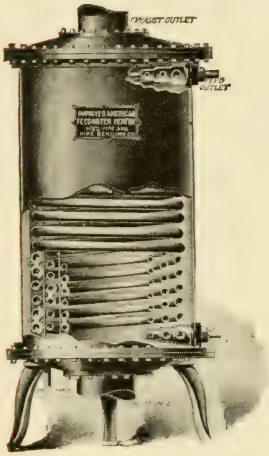
Class "C" Heater, Purifier and Filter.

5	500– 550	8	1½	4	47⅜	79½	21	86	44½	34⅛
7½	600– 750	10	2	5	57 3/4	92½	23	100	50	38¼
10	800–1200	10	2	5	55	92½	23	100	54	42¼
15	1300–1700	14	2½	6	68	104½	26½	112	61⅛	49¼
20	1800–2200	16	2½	6	67	104½	26	112	70½	5 ¼
25	2300–2700	18	3	8	69	105½	25	114	84	55¼
35	2800–4000	18	4	10	67	106½	25	116	120	55¼
50	4200–6000	18	6	10	67	107½	25	118	122½	70¼

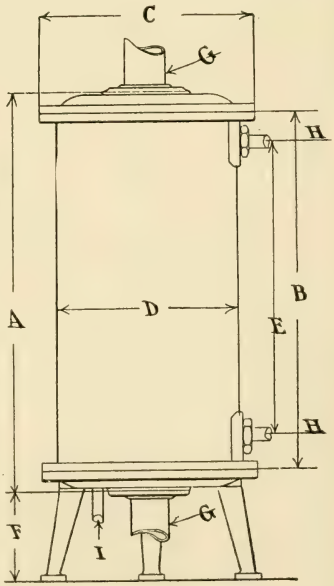
Note.—The selection of a heater depends both upon the quality of the feed water obtainable and the exhaust steam available. The above table shows only standard sizes of heaters. These can be modified both in size and in their constructive details to suit any unusual or peculiar conditions whatsoever.

Closed Feed Water Heaters.

The quantity of water that can be heated is limited by the amount of heat that can be transmitted through the walls of the tubes; the efficiency of that heat transmission is further decreased by the coating of oil that covers the steam side and the crust or scale that coats the water side of the tubes. No provision is made for purifying water in a closed heater, as the constant circulation of the water prevents the impurities from settling. Purification, if necessary, must therefore be done by means of auxiliary apparatus.



"American" Feed Water Heaters.—This heater consists of a coil, or series of coils, of seamless drawn, copper or brass, tubing, contained in a cast iron or steel shell. A single coil of tubing in all Heaters up to and including No. 10; above this size from two to six coils are used to give the requisite capacity for the amount of water required to pass through the coils. Special gun metal manifolds are used to connect the coils together at top and bottom inlet and outlet of feed water. This branch fitting is made of the best metal obtainable, into which the ends of the coils are inserted and brazed, the tubing not being weakened by expanding, and a full, unrestricted flow of water is secured to the coils.



Dimension Diagram.

American Feed Water Heaters, Concluded.

All joints inside the heater are brazed and strong.

The liability to leaky joints is obviated by the coils, which take care of contraction and expansion. The feed-water, passing through the coils while being heated to the boiling point, is under boiler pressure, consequently the brass or copper tubing is the only part of the heater under pressure, and the shell has simply to hold and convey the exhaust steam. All coils are guaranteed to stand 600 lbs. pressure.

There is practically no back pressure, since the area of the shell is six to ten times that of the exhaust pipe.

Dimension Table for the American Feed Water Heater.

Horse Power.	A	B	C	D	E	F	G	H	I	J	K	L	Mater'l in Shell.	Remarks.
10	17	14	9	7	12	.....	2	1½	1½	¾	.....	.....	STEEL.	Above 200 H. P. have combination flanges on exhaust openings. Up to 40 H. P. have no legs.
15	17	14	12	9	11	.....	2½	2	1½	1	.....	.....		
20	21	18	12	9	14	.....	2½	2½	1½	1	.....	.....		
25	25	19	18	15	16	.....	3	1	¾	1¼	.....	.....		
30	26	20	18	15	20	.....	3½	1	¾	1¼	.....	.....		
40	31	25	18	15	22	.....	4	1	¾	1¼	.....	.....		
50	34	27	20	17	20	12	4	1¼	1	1½	.....	.....		
60	41	34	20	17	29	12	4	1¼	1	1½	.....	.....		
80	46	39	20	17	34	12	5	1¼	1	1½	.....	.....		
100	52	45	20	17	40	12	5	1½	1¼	2	.....	.....		
125	47	40	24	20	35	12	6	1½	1¼	2	.....	.....		
150	52	45	24	20	40	12	6	1½	1¼	2	1½	.....		
200	51	44	27	23	35	15	8	2	1¼	1½	1½	.....		
250	57	50	27	23	40	15	8	2	1½	1½	1½	.....		
300	62	55	27	23	45	15	10	2	1½	1½	1½	1½		
400	63	55	34	28	46	15	10	2½	2	1½	1½	1½		
500	69	61	34	28	52	15	10	2½	2½	2	2	2		
600	77	67	38	32	57	15	12	3	3	2	2	2		
800	84	71	38	32	63	15	12	3	3	2½	2½	2		
1,000	82	82	48	42	59	15	16	4	4	2½	Four Coils of	2 in.		
1,250	93	82	48	42	70	15	16	4	4	2½	"	"		
1,500	108	97	48	42	85	15	18	4	4	2½	"	"		
2,000	113	102	56	49	90	18	20	5	5	3	Five	2 "	CAST IRON.	
2,500	108	97	70	60	85	18	20	5	5	3	Eight	2 "		
3,000	129	118	70	60	102	18	24	6	6	3	"	2 "		

Feed Water.

To convert water into steam at atmospheric pressure, it must be raised to the boiling point, which is 212 degrees Fahrenheit. The higher the temperature given to the feed water, therefore, the less coal is needed to convert it into steam. In general, a rise of ten degrees in the feed water results in a saving of one per cent. of coal used.

If the steam plant be one with a simple engine running non-condensing, the exhaust from it is conducted either partly or entirely through feed water heaters.

In the case of compound condensing engines, however, the only available exhaust steam comes from the auxiliaries, such as boiler feed pump, condenser, etc. This is considerable, however, as all direct acting steam pumps are large consumers of steam. If the supply of exhaust steam from the auxiliaries is not sufficient to raise the temperature to the highest point, yet the saving is considerable, and when taken in conjunction with fuel economizers a feed water temperature of 206 to 212 degrees is by no means uncommon.

Saving of Fuel by Heating Feed Water (in per cent., Steam at Sixty Pounds.)

Initial Tem. of Water.	Final Temperature of Feed Water.							
	120°	140°	160°	180°	200°	210°	250°	300°
32°	7.50	9.20	10.90	12.36	14.30	15 14	19.03	22.90
35	7.25	8.96	10.66	12.09	14.09	14.88	18.34	22.60
40	6.85	8.57	10.28	12.00	13.71	14.46	17.99	22.27
45	6.45	8.17	9.90	11.61	13.34	14.03	17.64	21.04
50	6.05	7.71	9.50	11.23	13.00	13.61	17.28	21.61
55	5.64	7.37	9.06	10.85	13.60	13.18	16.93	21.27
60	5.23	6.97	8.72	10.46	12.20	12.75	16.58	20.92
65	4.82	6.56	8.32	10.07	11.82	12.33	16.20	20.58
70	4.40	6 15	7.91	9.68	11.43	11.92	15.83	20.23
75	3.98	5.74	7.50	9.28	11.04	11.48	15.46	19.88
80	3.55	5.32	7.09	8.87	10.65	11.05	15.08	19.52
85	3.12	4.90	6.63	8.46	10.25	10.63	14.70	19.17
90	2.68	4.47	6.26	8.06	9.85	10 20	14.32	18.81
95	2.24	4.04	5.84	7.65	9.44	9.78	13.94	18.44
100	1.80	3.61	5.42	7.23	9.03	9.35	13.55	18.07
110	.90	2.73	4.55	6.38	8.20	8.50	12.76	17.28
120	0	1.84	3.67	5.52	7.36	7.65	11.95	16.49
130		.92	2.77	4.64	6.99	5.80	11.14	15.24
140		0	1.87	3.75	5.62	5.95	10.31	14.99
150			.94	2.83	4.72	5.10	9.46	14.18
160			0	1.91	3.82	4.25	8.59	13.37
170				.96	2.89	3.40	7.71	12.54
180				0	1.96	2.55	6.81	11.70
200					0	0.85	4.85	9.93

These results do not take into account the additional ben efit of the purifying action of open heaters on the feed water which is worth considering.

Feed Water, Continued.

Impurities of Water.—Water, as present in nature, is always more or less contaminated by impurities, so that for all refined measurements in which water plays the part of a standard, it must be in its distilled state; that is, absolutely pure.

In boiler practice, the exact composition of the water is of marked importance, as upon the impurities held in suspension or solution may depend, not only the economy of operation, but the very life of the boiler itself. The more common impurities, the character of the trouble which they cause, and the remedy or palliation to be applied, are indicated in the following table:

Troublesome Substance.	Trouble.	Remedy or Palliation.
Sediment, mud, clay, etc.	Incrustation.	Filtration. Blowing off.
Readily soluble salts.	Incrustation.	Blowing off.
Bicarbonate of lime, magnesia and iron.	Incrustation.	Heating feed, addition of caustic soda, lime or magnesia, etc.
Sulphate of lime.	Incrustation.	Addition of carbonate of soda, barium chloride.
Chloride or sulphate of magnesium.	Corrosion.	Addition of carbonate of soda, etc.
Carbonate of soda in large amounts.	Priming.	Addition of barium chloride, etc.
Acid (in mine waters.)	Corrosion.	Alkali.
Dissolved carbonic acid and oxygen.	Corrosion.	Heating feed, addition of caustic soda, slaked lime.
Grease (from condensed steam.)	Corrosion.	Slaked lime, and filtering, carbonate of soda, substitute mineral oil.
Organic matter (sewage.)	Priming.	Precipitate with alum or ferric chloride and filter.
Organic matter.	Corrosion.	Precipitate with alum or ferric chloride and filter.

Feed Water, Continued.

Purification.—The advantage of the live steam purifiers for use with badly incrustating water supplies is shown in the following table denoting the percentage of the lime thrown down at various temperatures.

217° F.,	50 % thrown down.	245° F.,	77.4% thrown down.
219° F.,	52.3% " "	250° F.,	81.7% " "
221° F.,	56.8% " "	255° F.,	86.0% " "
227° F.,	60 5% " "	261° F.,	90.3% " "
232° F.,	64.5% " "	266° F.,	94.0% " "
236° F.,	69.0% " "	271° F.,	97.7% " "
240° F.,	73.:% " "	290° F.,	100.0% " "

The heat conducting power of boiler scale is only 2.7% as great as that of the boiler shell. A scale deposit of $\frac{1}{8}''$ thickness in a boiler requires 15% more coal to be burned to produce the same steam than is needed for clean surfaces in the shell and tubes.

Feed Water Analysis.—The Hartford Steam Boiler Inspection & Insurance Company, realizing the importance of the subject, offer to make free analyses of feed water for such of their customers as desire it. The analysis of every sample of water involves considerable time and labor. It is important, therefore, that samples be taken strictly according to the following instructions:

"Procure a *new* quart *glass bottle* (which can be obtained of nearly any druggist), and a *new* cork to stopper it with.

Before collecting the sample, rinse the bottle thoroughly at least half a dozen times with the water from the source from which the sample is to be taken, filling the bottle about one-third full each time. Then fill it within about an inch of the stopper. Tie the stopper tightly down with a piece of strong twine so there will be no possibility of its coming out in transit. Label or tag bottle with your address and the source of the water. Do not seal it. If you pack the bottle in sawdust wrap it in paper first.

Precautions to be observed in collecting the samples: If the sample be taken from a well with a pump in it, pump about four gallons of water before allowing any to run into the bottle; then let the water run directly from the spout of

Feed Water, Concluded.

the pump into the bottle. If the sample be taken from a tap, let a few gallons run to waste: then let it flow directly from the tap into the bottle.

If the sample be intended to represent the water supply of a town, it must be taken from a pipe in direct communication with the street main, and not from a cistern or from any pipe supplied from a cistern, but it is rarely necessary to analyze a city supply or one generally used, as the experience of our inspectors over extended periods is better than deductions from analysis.

If the sample be taken from a tank, or well in which no pump is fixed, or stream of any kind, plunge the neck of the bottle completely below the surface, so as to avoid as much as possible collecting the water from the surface. On the other hand be careful not to stir up any mud or sediment at the bottom of the water.

Give as full information as possible on the following points:

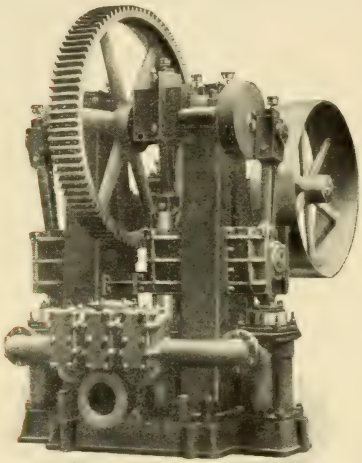
From what source the water is collected—wells, rivers, or streams, etc.

If from wells: Describe the diameter and depth of well, nature of soil, sub-soil, the water-bearing stratum into which the well is sunk, and the distance of the well from either drains, cesspools, or other possible sources of contamination, and describe their nature if any exist. New wells should be pumped from for two weeks or more to clear the water before sample is taken.

If from rivers or streams: Describe the character of the stream: at what point the sample was collected; whether it was taken directly from the stream or otherwise; and whether any possible sources of contamination, such as sewage or other polluting matter, exist on the stream above the point where the sample was collected.

It should be borne in mind that samples of water taken from wells less than 80 or 100 feet deep or from streams, after copious rains, do not fairly represent the average quality of the water, nor would the average quality be represented if the sample were collected in time of drought. It is therefore advisable that it be collected when the source of supply is at a fair average stage."

Blake Vertical Triplex Single Acting Power Pumps.



(For Boiler Feeding and Other Purposes.)

This type of power pump is a single acting machine, built with outside packed plungers; the plungers are submerged, thus keeping the pump primed all the time. The plungers are bolted to the crossheads, and can easily be removed. The water cylinders are made separate from the base of the pump. They are provided with deep stud gland stuffing boxes packed from the outside. The water chest is so constructed that it can be separated from the water cylinders for repairs. The chest cover or hand hole plate is held in place by studs and nuts, and when removed gives easy access to all the water valves. The water valves are of the disc type, either rubber or metal. Provision is also made for ball valves, if desired. The cross-heads are guided and provided for taking up wear; the connecting rods have wedge and screw attachment. The valve area and water ways are large, and the design is such as to make all the working parts easily accessible.

Note.—The capacities in the tables on the two following pages are based upon cold water service; for hot water, such as boiler feeding, the speeds should be approximately 33⅓% less and the capacities are correspondingly reduced.

Blake Vertical Triplex, Single Acting Pumps, Continued.

(Suitable for 60 Pounds Water Pressure.)

Size		Capacity			Diam. Pipes		Tight and Loose Pulleys			Ratio of Gearing	Approximate Dimensions in feet and inches		
Diameter of Plungers	Length of Stroke	Gallons per Revolution	Revolutions per Minute	Gallons per Minute	Suction	Discharge	Diameter	Face	Belt *		Length	Width	Height
5	8	2.03	45	91	4	3	30	5½	S	4.7-1	3-10	3- 9	5-7
5½	8	2.46	45	110	4	3	30	5½	S	4.7-1	3-10	3- 9	5-7
6	8	2.93	45	132	4	3	30	5½	S	4.7-1	3-10	3- 9	5-7
6½	8	3.42	45	154	5	4	30	5½	S	4.7-1	4- 0	4- 1	5-7
7	8	4.00	45	180	5	4	30	5½	S	4.7-1	4- 0	4- 1	5-7
8	8	5.22	45	235	6	5	30	7½	S	5.0-1	4- 8	4-11	6-5

(Suitable for 100 Pounds Water Pressure.)

5	8	2.03	45	91	4	3	30	5½	S	4.7-1	3-10	3- 9	5-7
5½	8	2.46	45	110	4	3	30	5½	S	4.7-1	3-10	3- 9	5-7
6	8	2.93	45	132	4	3	30	5½	S	4.7-1	3-10	3- 9	5-7
6½	8	3.42	45	154	5	4	30	5½	S	4.7-1	4- 0	4- 1	5-7
7	8	4.00	45	180	5	4	30	7½	S	5.0-1	4- 8	4-11	6-5
8	8	5.22	45	235	6	5	30	7½	S	5.0-1	4- 8	4-11	6-5

(Suitable for 150 Pounds Water Pressure.)

5	8	2.03	45	91	4	3	30	5½	S	4.7-1	3-10	3- 9	5-7
5½	8	2.46	45	110	4	3	30	5½	S	4.7-1	3-10	3- 9	5-7
6	8	2.93	45	132	5	4	30	7½	S	5.0-1	4- 8	4-11	6-5
6½	8	3.42	45	154	5	4	30	7½	S	5.0-1	4- 8	4-11	6-5
7	8	4.00	45	180	5	4	30	7½	D	5.0-1	4- 8	4-11	6-5

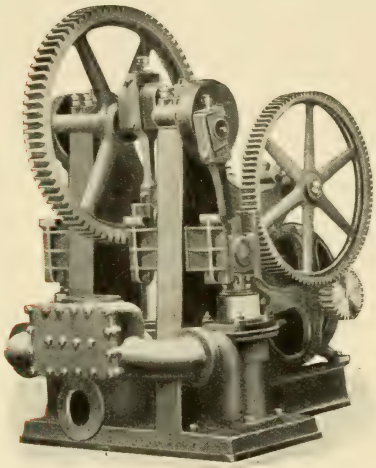
(Suitable for 225 Pounds Water Pressure.)

3	8	.73	45	33	3	2½	30	7½	S	5.0-1	4- 8	4-11	6-5
4	8	1.30	45	58	3	2½	30	7½	S	5.0-1	4- 8	4-11	6-5
5	8	2.03	45	91	4	3	30	7½	S	5.0-1	4- 8	4-11	6-5
6	8	2.93	45	132	5	4	42	6½	D	4.8-1	6- 5	5- 4	6-8
6½	8	3.42	45	154	5	4	42	6½	D	4.8-1	6- 5	5- 4	6-8
7	10	4.99	42	210	5	5	42	11½	D	4.8-1	6- 6	5- 9	7-5
7½	10	5.73	42	240	6	5	42	11½	D	4.8-1	6- 6	5- 9	7-5
8	10	6.52	42	274	6	5	42	11½	D	4.8-1	6- 6	5- 9	7-5
8	12	7.83	40	313	6	6	46	12½	D	5.0-1	6-10	7- 1	9-2
8½	12	8.82	40	353	7	6	46	12½	D	5.0-1	6-10	7- 1	9-2
9	12	9.91	40	396	7	6	60	10½	D	5.0-1	9- 0	9- 0	9-2
10	12	12.24	40	489	8	7	60	13½	D	5.0-1	9- 0	9- 0	9-2

* S indicates single and D double belt.

Above pumps may be safely run at 25 per cent. greater speed than listed.

Blake Vertical Single Acting Triplex Pumps, Concluded.



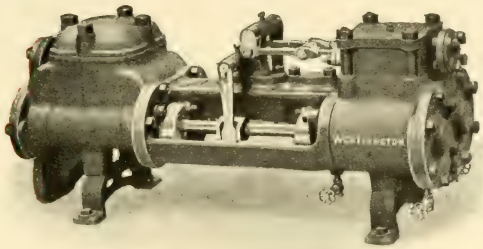
Electric Driven Pump.– This pump is similar in all respects to those on the preceding page, except that it has a double reduction of gears for driving with motor or extended base.

(See note on page 566.)

Diameter of Plungers.	Length of Stroke.	Revolutions per Minute.	Gallons per Minute.	In Inches.		In feet and Inches.			Motor Horse Powers Required at pressures of		
				Suction.	Discharge.	Length.	Width.	Height.	60 lbs.	100 lbs.	150 lbs.
2¾	6	50	23	3	2½	3- 7	2-11	4-3	1½	2½	5
3	6	50	27	3	2½	3- 7	2-11	4-3	1½	2½	5
4	6	50	50	3	2½	3- 7	2-11	4-3	3	5	7½
4½	6	50	62	4	3	3- 7	3- 4	4-9	5	7½	7½
5	6	50	75	4	3	3- 7	3- 4	4-9	5	7½	10
5	8	45	91	4	3	3-10	3- 9	5-7	7½	10	15
5½	8	45	110	4	3	3-10	3- 9	5-7	7½	10	15
6	8	45	132	4	3	3-10	3- 9	5-7	10	15	20
6½	8	45	154	5	4	4- 0	4- 1	5-7	10	15	20
7	8	45	180	5	4	4- 8	4-11	6-5	10	15	25

Note.—The gears usually furnished consist of a double reduction of 5 to 1 each. This gives a motor speed of 25 times the number of revolutions indicated above for the pump. Any reasonable variation and modification from this standard can of course be made.

Worthington Boiler Feed Duplex Steam Pumps.



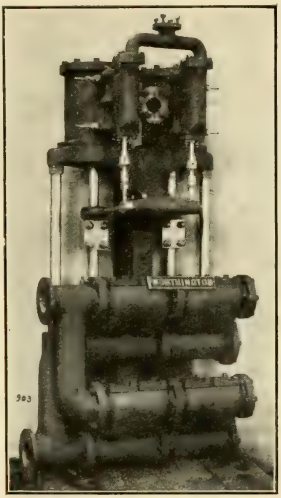
Piston Pattern, Good for 150 lbs. Pressure.—The working parts of these pumps are drop forged steel. Also pipe connections are flanged and fitted with companion flanges. One of the steam valves is always open, consequently there is no dead point. The plunger is double acting, working through a deep metallic packing ring, bored to an accurate fit. Both the ring and the plunger can be quickly taken out and refitted or replaced.

These pumps are fitted with packed water pistons of iron or brass, as may be required, operating in brass-lined cylinders. The water valves are of brass or hard composition, and are controlled by brass cylindrical springs, held in place by guards of the same material.

The following are the standard sizes:

Diameter of Steam Cylinders.	Diameter of Water Pistons.	Length of Stroke.	Horse Power of Boiler, based on 30 lbs. of Water per hour, which the Pump will Supply with ease.	Sizes of Pipes for Short Length. To be Increased as Length Increases.			
				Steam Pipe.	Exhaust Pipe	Suction Pipe.	Discharge Pipe.
2	1⅛	2¾	35	⅜	½	1	¾
3	2	3	100	⅜	½	1¼	1
4½	2¾	4	200	½	¾	2	1½
5¼	3½	5	400	¾	1¼	2½	1½
6	4	6	550	1	1¼	3	2
7½	5	6	800	1½	2	4	3
7½	4½	10	950	1½	2	4	3
9	5¼	10	1300	2	3	5	4
10	6	10	1700	2	2½	5	4

Worthington Boiler Feed Pumps, Continued.



Admiralty Pattern, for 250 lbs. Pressure.—This form of pump was originally designed to meet the requirements of the British Admiralty, and modified to conform to the views of the United States Bureau of Steam Engineering. It has since been adopted for boiler feeding by many of the larger plants in the country in connection with high pressures.

The steam end is of the well-known Worthington type, but embodies some of the latest patented features. The ordinary slide valves have in the case of this design been substituted by improved piston valves with outside adjustable lost motion links, making it possible to readily adjust the stroke. The water end is made of composition, gun metal, or cast iron sufficiently strong to work against a pressure of 250 pounds. When made of cast iron the water end is thoroughly brass fitted, viz.: Brass rods, cylinder linings and pistons.

In accordance with the latest practice, these pumps are intended to run without cylinder lubrication.

Worthington Boiler Feed Pumps, Concluded.

Table of Sizes and Dimensions for Admiralty Pattern 250 lb. Pressure Pump.

Diameter of Steam Cylinder.	Diameter of Water Pistons.	Length of Stroke.	Horse Power of Boiler, based on 30 Pounds of Water per Hour, which the Pump will supply with ease.	Diameter of Pistons required in any Single Cylinder Pump to do the Same Work at Same Speed.	Sizes of Pipes for Short Lengths. To be Increased as Length Increases.				Height over all in feet and Inches.
					Steam Pipe.	Exhaust Pipe.	Suction Pipe.	Discharge Pipe.	
4½	2¾	4	400	4¾	½	3	2	2	2–10
5¼	3½	5	550	5	¾	1¼	2½	2½	3–10
6	4	6	750	5⅝	1	1¼	4	3	4–1
7½	4½	6	1000	6⅜	1¼	1¼	4	3	4–1
9	5	6	1200	7⅛	1½	2	5	4	4–6
7½	4½	10	1400	8⅛	1½	2	5	4	4–9
9	6	10	2100	6⅜	2	2½	4	3	5–8
10	7	10	2900	8⅛	2	2½	5	4	5–8
12	8½	10	4200	9⅞	2½	2½	6	5	6–5
12	9¼	10	5000	12	2½	3	6	5	7–10
14	10	15	7000	13	2½	3	6	5	7–11
				14	2½	3	8	6	9–0

GENERAL PUMP DATA.

Table of Theoretical Steam Consumption of Pumps, at a Piston Travel of 100 Feet per Minute.

Diameter of Cylinder.	Cubic Feet per Minute.	INITIAL STEAM PRESSURE.									
		60	70	80	90	100	110	120	130	140	150
		STEAM CONSUMPTION IN POUNDS PER HOUR.									
8	34.9	365	410	455	500	540	585	630	670	720	760
9	44.3	465	507	575	630	690	740	800	855	920	964
10	54.5	570	640	710	780	845	915	985	1050	1125	1185
11	66	690	770	860	940	1020	1110	1190	1270	1360	1435
12	78.5	820	820	1020	1120	1220	1320	1420	1520	1620	1710
14	107	1120	1250	1390	1530	1660	1800	1940	2070	2210	2330
16	139.6	1460	1625	1810	2000	2160	2350	2530	2700	2880	3040
18	176.7	1850	2070	2290	2530	2750	2970	3200	3420	3650	3850
20	218.2	2290	2550	2840	3120	3380	3660	3950	4200	4500	4750
22	264	2760	3090	3430	3760	4100	4430	4780	5090	5440	5750
24	314	3290	3660	4070	4490	4860	5270	5680	6060	6480	6820
26	369	3870	4310	4800	5270	5720	6200	6680	7110	7600	8020
28	428	4490	5000	5560	6110	6650	7190	7750	8260	8820	9310
30	491	5160	5750	6390	7010	7610	8250	8880	9490	10120	10680

Example:—To determine the steam consumption of a 12 and 18 x 12 x 18 Duplex Compound Pump: Piston speed 85 feet per min.: Initial Steam pressure 100 pounds.

Since the pump is duplex and since live steam enters the high pressure cylinders only, the theoretical consumption would be double that of a single 12″ cylinder; or at 100 feet piston speed, 1220 x 2=2440 pounds per hour.

Theoretical consumption at 85 feet piston speed, 2440 x .85 =2074 pounds per hour.

The actual steam consumption exceeds the theoretical by 20 per cent. to 50 per cent.

The area of the steam piston, multiplied by the steam pressure, gives the total amount of pressure exerted. The area of the water piston, multiplied by the pressure of water per square inch, gives the resistance. A margin must be made between the power and resistance to move the pistons at the required speed; usually reckoned at from 25 to 50 per cent.

Note.—Where steam cylinders of condensers are exhausted into the receivers of Compound Engines (see page 577) this table will be found convenient for making the necessary calculations.

General Pump Data, Continued.

Quantitative Discharge of One Piston or Plunger.

(Computed on piston velocity of 100 feet per minute, of a double-acting piston, no allowance being made for slip, which varies from five to ten per cent.)

Diameter Piston.	Gallons per		Diameter Piston.	Gallons per	
	Minute.	Hour.		Minute.	Hour.
4	65.2	3916	14¼	828	49704
4¼	73.7	4422	14½	858	51468
4½	82.6	4957	14¾	887	53256
4¾	92	5523	15	918	55070
5	102	6120	15¼	949	56928
5¼	112	6745	15½	980	58800
5½	123	7404	15¾	1012	60720
5¾	134	8093	16	1044	62668
6	146	8812	16¼	1077	64638
6¼	159	9562	16½	1110	66642
6½	172	10344	16¾	1144	68676
6¾	185	11152	17	1179	70752
7	200	11995	17¼	1214	72840
7¼	214	12867	17½	1249	74964
7½	229	13769	17¾	1285	77124
7¾	245	14700	18	1322	79314
8	261	15667	18¼	1359	81528
8¼	277	16660	18½	1396	83778
8½	294	17688	18¾	1434	86060
8¾	312	18741	19	1473	88368
9	330	19828	19¼	1511	90660
9¼	349	20944	19½	1552	93120
9½	368	22092	19¾	1590	95400
9¾	388	23280	20	1632	97920
10	408	24480	20¼	1673	100380
10¼	428	25716	20½	1714	102840
10½	449	26989	20¾	1756	105396
10¾	471	28290	21	1799	107952
11	493	29616	21¼	1842	110538
11¼	516	30986	21½	1886	113154
11½	539	32374	21¾	1930	115800
11¾	564	33795	22	1974	118482
12	587	35251	22¼	2020	121194
12¼	612	36735	22½	2065	123924
12½	637	38250	22¾	2111	126696
12¾	663	39816	23	2158	129492
13	689	41370	23¼	2205	132324
13¼	716	42972	23½	2253	135186
13½	743	44610	23¾	2301	138078
13¾	771	46278	24	2349	140958
14	799	47980			

The above figures are all U. S. gallons. To determine quantity discharged by two pistons (as for a duplex pump), multiply by 2. To determine quantity discharged by three single acting plungers (as for a triplex pump), multiply by 1½. For piston speeds other than 100 feet per minute, computations may be easily made.

Table of Theoretical Horse Power Required to Raise Water to Different Heights.

Gallons per Min.	5 Ft.	10 Ft.	15 Ft.	20 Ft.	25 Ft.	30 Ft.	40 Ft.	50 Ft.	75 Ft.	100 Ft.	125 Ft.	150 Ft.	175 Ft.	200 Ft.	250 Ft.	300 Ft.	350 Ft.	400 Ft.	Gallons per Min.
5	.006	.012	.019	.025	.031	.037	.05	.06	.09	.12	.16	.19	.22	.25	.31	.37	.44	.50	5
10	.012	.025	.037	.050	.062	.075	.10	.12	.19	.25	.31	.37	.44	.50	.62	.75	.87	1.00	10
15	.019	.037	.056	.075	.094	.112	.15	.19	.28	.37	.47	.56	.66	.75	.94	1.12	1.31	1.50	15
20	.025	.050	.075	.100	.125	.150	.20	.25	.37	.50	.62	.75	.87	1.00	1.25	1.50	1.75	2.00	20
25	.031	.062	.093	.125	.156	.187	.25	.31	.47	.62	.78	.94	1.09	1.25	1.56	1.87	2.19	2.50	25
30	.037	.075	.112	.150	.187	.225	.30	.37	.56	.75	.94	1.12	1.31	1.50	1.87	2.25	2 62	3.00	30
35	.043	.087	.131	.175	.219	.262	.35	.44	.66	.87	1.08	1.31	1.53	1.75	2.19	2.62	3.06	3.50	35
40	.050	.100	.150	.200	.250	.300	.40	.50	.75	1.00	1.25	1.50	1.75	2.00	2.50	3.00	3.50	4.00	40
45	.056	.112	.168	.225	.281	.337	.45	.56	.84	1.12	1.41	1.69	1.97	2.25	2.81	3.37	3.94	4.50	45
50	.062	.125	.187	.250	.312	.375	.50	.62	.94	1.25	1.56	1.87	2.19	2.50	3.12	3.75	4.37	5.00	50
60	.075	.150	.225	.300	.375	.450	.60	.75	1.12	1.50	1.87	2.25	2.62	3.00	3.75	4.50	5.25	6.00	60
75	.093	.187	.281	.375	.469	.562	.75	.94	1.40	1.87	2.34	2.81	3.28	3.75	4.69	5.62	6.56	7.50	75
90	.112	.225	.337	.450	.562	.675	.90	1.12	1.68	2.25	2.81	3.37	3.94	4.50	5.62	6.75	7.87	9.00	90
100	.125	.250	.375	.500	.625	.750	1.00	1.25	1.87	2.50	3.12	3.75	4.37	5.00	6.25	7.50	8.75	10.00	100
125	.156	.312	.469	.625	.781	.937	1.25	1.56	2.34	3.12	3.91	4.69	5.47	6.25	7.81	9.37	10.94	12.50	125
150	.187	.375	.562	.750	.937	1.125	1.50	1.87	2.81	3.75	4.69	5.62	6.56	7.50	9.37	11.25	13.12	15.00	150
175	.219	.437	.656	.875	1.093	1.312	1.75	2.19	3.28	4.37	5.47	6.56	7.66	8.75	10.94	13.12	15.31	17.50	175
200	.250	.500	.750	1.000	1.250	1.500	2.00	2.50	3.75	5.00	6.25	7.50	8.75	10.00	12.50	15.00	17.50	20.00	200
250	.312	.625	.937	1.250	1.562	1.875	2.50	3.12	4.69	6.25	7.81	9.37	10.94	12.50	15.72	18.75	21.87	25.00	250
300	.375	.750	1.125	1.500	1.875	2.250	3.00	3.75	5.62	7.50	9.37	11.25	13.12	15.00	18.75	22.50	26.25	30.00	300
350	.437	.875	1.312	1.750	2.187	2.625	3.50	4.37	6.56	8.75	10.94	13.12	15.31	17.50	21.87	26.25	30.62	35.00	350
400	.500	1.000	1.500	2.000	2.500	3.000	4.00	5.00	7.50	10.00	12.50	15.00	17.50	20.00	25.00	30.00	35.00	40.00	400
500	.625	1.250	1.875	2.500	3.125	3.750	5.00	6.25	9.37	12.50	15.62	18.75	21.87	25.00	31.25	37.50	43.75	50.00	500

This table gives the actual water horse power. When selecting motors or turbines allowance must be made for pipe friction and loss in the pump, gears, belts, etc. One foot head equals .43 pounds pressure to the square inch.

To find the quantity of water elevated in one minute running at 100 feet of piston per minute, square the diameter of water cylinder in inches and multiply by 4. Example: capacity of a five-inch cylinder is desired: the square of the diameter (5 inches) is 25, which multiplied by 4 gives 100, which is gallons per minute (approximately).

General Pump Data, Concluded.

Friction of Water in Pipes.

(Loss in pounds Pressure per Square Inch by Friction, for Each One Hundred Feet of Straight Smooth Pipe, Discharging the Stated Quantities per Minute.)

U. S. Gallons.	SIZE OF PIPES.														
	1 in.	1½	2	2½	3	4	6	8	10	12	14	16	18	20	24
5	0.84	0.12													
10	3.16	0.47	0.12												
15	6.98	0.97	0.27												
20	12.3	1.66	0.42												
25	19.0	2.62	0.67	0.21											
30	27.5	3.75	0.91	0.30											
35	37.0	5.05	1.26	0.42	0.14										
40	48.0	6.52	1.60	0.51	0.17										
45		8.15	2.01	0.61	0.27										
50		10.0	2.44	0.81	0.35	0.09									
75		22.4	5.32	1.80	0.74	0.21									
100		39.0	9.46	3.20	1.31	0.33	0.05								
125		48.1	14.9	4.89	1.99	0.51	0.07								
150			21.2	7.00	2.85	0.69	0.10	0.02							
175			28.1	9.46	3.85	0.95	0.14	0.03							
200			37.5	12.47	5.02	1.22	0.17	0.04	0.01						
250			47.7	19.66	7.76	1.89	0.26	0.06	0.02						
300				28.06	11.2	2.66	0.37	0.09	0.03	0.005					
350				33.41	15.2	3.65	0.50	0.11	0.05	0.007	.004				
400				42.96	19.5	4.73	0.65	0.15	0.06	0.01	.005	.001			
450					25.0	6.01	0.81	0.20	0.08	0.02	.008	.004			
500					30.8	7.43	0.96	0.25	0.09	0.04	.017	.009	.005		
600						9.54	1.41	0.38	0.14	0.07	.026	.014	.007		
700						14.32	1.89	0.47	0.18	0.08	.034	.017	.010	.002	
800							2.38	0.61	0.22	0.09	.045	.023	.012	.004	
900							2.60	0.78	0.27	0.11	.055	.028	.015	.008	.001
1000							3.88	0.94	0.32	0.13	.062	.036	.020	.012	.005
1250								1.46	0.49	0.20	.091	.049	028	.021	.009
1500								2 09	0.70	0.29	.135	.071	.040	.030	.014
2000									1.23	0.49	.234	.123	.071	.042	.020
2500										0.77	.362	.188	.107	.064	.032
3000										1.11	.515	.267	.150	.091	.047
3500											.697	.365	.204	.124	.055
4000											.910	.472	.263	.158	.067
4500												.593	.333	.189	082
5000												.730	.408	.244	.102

The friction loss is greatly increased by bends or irregularities in the pipe.

The friction increases with the square of its velocity.

The quantity of flow through pipes increases with the square root of the fifth power of the pipe diameters; doubling the diameter increases the quantity of flow 5.66 times.

To find the pressure in pounds per square inch, due to forcing a given quantity of water through a certain size of pipe, consult the table of Friction of Water in Pipes. Add the amount of this friction to the pressure due to the height to which water is to be forced, and the result is total water pressure.

CONDENSING APPARATUS

The three general types of condensing apparatus described and illustrated on the following pages will be found to meet practically all conditions pertaining to the application of the principles of condensation and the production of a vacuum.

The following table is given in order readily to show the advantages of each type and to assist in the selection of the one most appropriate for the service in mind:

1. **Jet Condensers.**—To be used where the water supply for condensation is fresh and of sufficiently good quality for boiler feed Or, where the water supply for condensation is unfit for boiler feed, being contaminated with lime or salt, but a fresh supply of water can be had for boiler feed.

2. **Surface Condensers.**—To be used where a water supply for condensation is unfit for boiler feed, and distilled water is necessary, there being no other suitable supply available. This type of condenser is also used with turbo-generators, as turbines give the best results with vacuums of 28 inches and upwards.

3. **Self-Cooling Condensers,** "Cooling Towers."—To be used where the entire water supply is limited to boiler feed water, there being no sufficient natural water supply of any kind for condensing purposes:

(a) With **Jet Condenser** when the boiler feed-water is suitable for use in the boilers.

(b) With **Surface Condenser** when the boiler feed-water is contaminated with lime, and distilled water is desired for the boilers.

WORTHINGTON JET CONDENSERS.

In order that the practical results attained by condensing engines should approximate those that theory indicates, it is important that the condensing apparatus employed should be the most efficient possible; that it should maintain the highest vacuum with the least cost of production; that it should be regular and reliable in action; simple in construction; and that its application to the engine should be unaccompanied by any risk of accident.

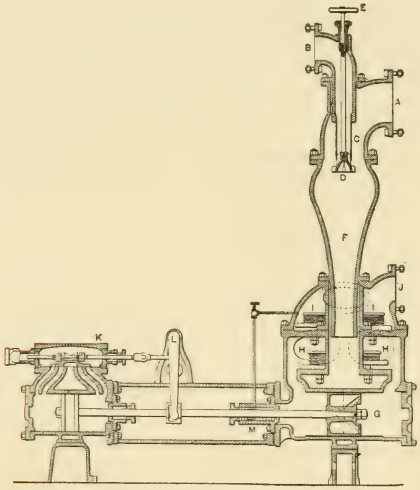
Exhaust steam from an engine enters a vacuum with a velocity of about 1,900 feet per second, and water under atmospheric pressure with a velocity of 47 feet per second. Excepting the machine herein described, it may be said that in all forms of jet condensers operated by air pumps the injection water and the water from the steam fall to the bottom of the condensing chamber, come to a rest before entering the pump, and consequently lose the value of the momentum acquired when entering the vacuous space.

The air set free by the condensation of the steam is intermingled with the water. There is here a great distinction between a jet condenser pumping aerated water and an air pump pumping air and water unmixed. In the latter case the air pump has a varying and irregular duty to perform, and the inevitable result is an irregular and slamming movement.

A most important advantage of this condenser is that it is practically impossible for the injection water to be drawn into the steam cylinders of the main engine while it is running. The serious danger of flooding is avoided without the use of floats, check valves, or other automatic contrivances.

Note—Simple jet condensers can often be exhausted into the receiver between the high and low pressure cylinders of the main engine and thereby improve upon even the performance of a condenser having compound steam cylinders.

Worthington Jet Condensers, Continued.



Sectional View of Worthington Jet Condenser.

The above illustration shows a longitudinal section of one side of the condenser pump, and also a section of the condenser cone, spray pipe, exhaust elbow and injection elbow. "A" is the opening to which is connected the pipe that conducts to the condenser the steam that is to be condensed and in which a vacuum is to be made and maintained. This injection opening must not be more than twenty feet above the surface of the water supply when the apparatus is used with engines, and fifteen feet when in connection with vacuum pans. "C" is the spray pipe, and has, at its lower extremity, a number of vertical slits through which the water of injection passes and becomes spread out into thin sheets. The spray cone "D," by means of its serrated surface, breaks the water passing over it into fine spray, and thus ensures a rapid and thorough intermixture with the steam.

Worthington Jet Condensers, Continued.

This spray cone "D" is adjustable by means of a stem passing through a stuffing-box at the top of the condenser, and is operated by the handle "E." Any floating material that can pass an ordinary strainer will not lodge around this spray cone, but should it become obstructed from any cause, it can be washed clear by simply lowering the spray cone by means of the handle and stem. In order to lower the cone, the handle should be turned to "open," that is, in the direction opposite to the movement of the hands of a clock. When the foreign material has been carried away by the water, the cone may be returned to its proper position by turning the handle in the reverse direction as far, or nearly as far, as it will go. The cone should be left far enough down to allow the quantity of water needed for condensation to pass. All regulation of the injection water must be done by an injection valve placed in the injection pipe at a convenient point.

The piston pump "G" is of the well-known Worthington type. The water cylinders are lined with composition; the glands of the stuffing-boxes and the valve-seats, plates, guards and springs are of the same material.

"H H" shows the position of the injection and "I I" of the discharge valves. "J" is the discharge opening. At "K" the steam end of the machine.

The operation is as follows: Steam being admitted to the cylinders "K," a vacuum is formed in the condenser, the engine cylinder, the connecting exhaust pipe, and the injection pipe. This causes the injection water to enter through the injection pipe attached at "B" and spray pipe "C" into the condenser cone "F." The main engine is then started, the exhaust steam enters through the exhaust pipe at "A," and, coming in contact with the cold water is rapidly condensed. The velocity of the steam is communicated to the water, and the whole passes through the cone "F" into the pump "G" at a high velocity, carrying with it, in a thoroughly commingled condition, all the air or uncondensable vapor which enters the condenser with the steam. The mingled air and water is discharged by the pump through the valves and pipe at "J" before sufficient time or space has been allowed for separation to occur.

Worthington Jet Condensers, Continued.

Table of Sizes and Dimensions.

(In inches unless otherwise stated.)

*Diameter of Steam Cylinders.	Diameter of Water Cylinders.	Length of Stroke.	Sizes of Pipes.					Approximate over all Dimensions. in feet and inches.		
			Steam Pipe of Pump.	Exhaust Pipe of Pump.	Exhaust Inlet.	Injection Opening.	Discharge Opening.	Length.	Width.	Height.
7½	8½	10	1½	2	12	5	5	6–3	2–3	7–6
7½	8⅝	10	1½	2	12	5	5	6–3	2–3	7–6
7½	10¼	10	1½	2	14	7	8	6–3	2–8	7–6
9	12	10	2	2½	14	7	10	7–7	2–8	7–6
12	14	10	2½	3	16	8	10	7–7	3–3	9–8
12	15	10	2½	3	16	8	10	7–7	3–3	9–8
12	15	15	2½	3	18	10	10	8–3	3–9	9–8
12	17	15	2½	3	18	10	12	9–0	4–1	10–1
14	17	15	2½	3	18	10	12	9–0	4–1	10–1
14	19	15	2½	3	18	10	12	9–0	4–1	10–1
17	19	15	2½	3½	18	10	12	9–3	4–1	10–1
14	22	15	2½	3	20	10	14	9–3	4–7	12–3
17	22	15	2½	3½	20	10	14	9–3	4–7	12–3
18	26	18	2½	4	24	12	18	10–9	5–10	14–6
18	22	18	4	4	20	10	14			
18	24	18	4	4	20	10	14			
18	26	18	4	4	24	12	16			
18	29	18	4	4	24	14	18			

*Steam cylinders of larger diameter can be applied where steam of very low pressure is used or where the discharge water is to be elevated.

The sizes in column headed, "Steam Pipe of Pump," are selected to cover cases in which the steam pipe is very long, but, ordinarily, these pipes may be very much reduced in diameter.

Note.—These tables are simply approximate, and are to be used for estimating purposes for preliminary work only. The details of the apparatus are necessarily changed from time to time to keep abreast of the latest ideas and improvements. Therefore detailed drawings should be obtained in each case from the builder for the purpose of laying out and installation.

Worthington Jet Condensers, Continued.

Amount of Water Required to Condense.

The amount of water required to thoroughly condense the steam from an engine is dependent upon two conditions—the total heat and weight of the steam, and the temperature of the injection water. The former represents the work to be done, and the latter the value of the water by whose cooling agency the condensation of the steam is to be accomplished

Generally stated, with 26 inches vacuum and injection water at ordinary temperature (not exceeding 70° Fahr.), from 20 to 30 times the quantity of water evaporated in the boilers (feed water) will be required for the complete liquefaction of the exhaust steam from an engine. The potency of the injection water decreases very rapidly as the temperature increases. On the other hand, if the temperature be lower, less water is required.

To estimate the value of water for condensing purposes under any specific conditions, the following formula will be of assistance:

Given: t=Temperature of injection water.
T=Temperature of discharge water.
H=Total heat (sum of sensible and latent heat) of the steam at the pressure at which it leaves the engine. This varies from 1,140 to 1,158 units above 32 degrees, as the terminal pressure is 10 pounds or 30 pounds absolute. It may, however, be taken as 1,190 (1,158 + 32) for ordinary purposes in this formula. *

Then: $\frac{H-T}{T-t}$ = Unit weights of injection water required per unit weight of steam.

Example: t=70° Fahr.
T=110° Fahr. with a vacuum of 26 inches.
H=1,190 units of heat

Hence: $Q=\frac{1,190-110}{110-70}=27$, where—
Q=Pounds of water required to condense one pound of steam.

Upon a test with no air leaks it might be possible to carry

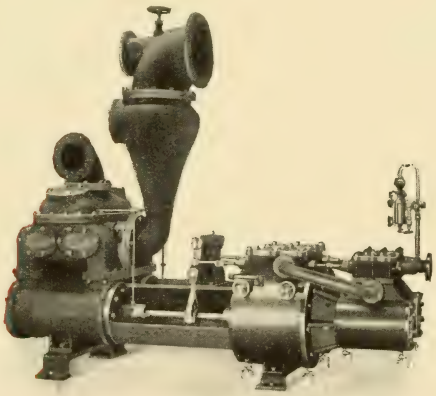
* See pages 598-'9.

Worthington Jet Condensers, Continued.

the discharge water to a higher temperature than 110°, thus reducing the quantity of condensing water required. As a general rule, it may be stated that a temperature of discharge water within 15° of the temperature corresponding to the vacuum in the condensing chamber, is as high as can be expected in actual service.

The amount of water handled by the jet condenser is calculated upon a basis of thirty to forty revolutions per minute according to size; as these machines are all duplex, it should be remembered that each cylinder is required to handle only one-half the amount of water needed.

Note.—In determining the proper size of condenser, allow about fifty per cent. for air and uncondensed vapors and five per cent. slip.



Horizontal Compound Jet Condensers.

This type of compound jet condenser is best adapted to the smaller sizes; for the larger work the vertical compound machines, described on a subsequent page, are to be recommended.

When the exhaust steam from the condenser pump can be

Worthington Jet Condensers, Concluded.

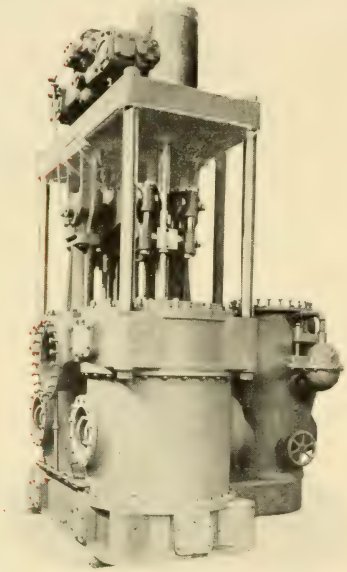
used to heat the boiler feed-water or compounded into the main engine receiver, the ordinary form of steam cylinders is recommended, both on account of economy and simplicity. There are, however, cases where this cannot be done, and it becomes advisable to compound the steam cylinders, so that the steam may be used expansively and with high economy. The condenser pump itself may be run condensing by exhausting into the main exhaust pipe, and the benefit of the vacuum obtained upon it.

Table of Sizes and Dimensions.
Horizontal Compound Jet Condensers,
(In inches unless otherwise stated.)

Diameter of Steam Cylinders.	Diameter of Water Cylinders.	Length of Stroke.	Sizes of Pipes.					Approximate over all Dimensions, in feet and inches.		
			Steam Pipe of Pump.	Exhaust Pipe of Pump.	Exhaust Inlet.	Injection Opening.	Discharge Opening.	Length.	Width.	Height.
5¼ & 7½	8½	10	1¼	2	12	5	5	8-0	2-4	7-6
6 & 9	10¼	10	1¼	2½	14	7	6	8-0	2-7	7-6
6 & 9	12	10	1¼	2½	14	7	8	8-0	2-7	7-6
8 & 12	14	10	2	3	16	8	10	9-6	3-3	8-0
8 & 12	15	10	2	3	16	8	10	9-6	3-3	8-0
10 & 17	15	15	2½	3½	18	10	10	9-6	3-3	8-0
10 & 17	17	15	2½	3½	18	10	12	12-4	4-1	10-1
10 & 17	19	15	2½	3½	18	10	12	12-4	4-1	10-1
12 & 17	22	15	2½	5	20	10	14	12-8	4-7	12-3
12 & 22	26	18	2½	6	24	12	18	13-4	6-5	14-6
14 & 25	29	18	2½	7	24	14	18	13-4	6-5	14-6
16 & 29	32	18	4	8	28	16	20	13-4	6-5	14-6
16 & 30	36	24	4	8	30	18	22			

Note.—These tables are simply approximate, and are to be used for estimating purposes for preliminary work only. The details of the apparatus are necessarily changed from time to time to keep abreast of the latest ideas and improvements. Therefore detailed drawings should be obtained in each case from the builder for the purpose of laying out and installation.

BLAKE JET CONDENSERS.



Vertical "Twin" Air Pump and Jet Condenser.

The demand for an air pump and jet condenser of large size to occupy the least possible floor space, and still have all its moving parts easily accessible, has led to the design and construction of this type of apparatus.

The above cut shows the pump with the condensing chamber in its usual position at the rear, connected directly with the channel plate at the bottom of the pump. The injection opening can be placed on either side of the condensing chamber, and the hand wheel for regulating the spray on the opposite side. The discharge opening is in front. The steam pipe also connects in front, and the exhaust pipe in the rear, where it is conveniently situated to drop down into the condensing chamber if it is desired to have the apparatus condense its own exhaust.

With these twin condensers it is very good practice to

Blake Jet Condensers, Concluded.

turn their exhaust into the receiver of the main engine and componud it through the low pressure cylinder, thus securing the economy of a Corliss engine.

(For steam consumption, see page 572.)

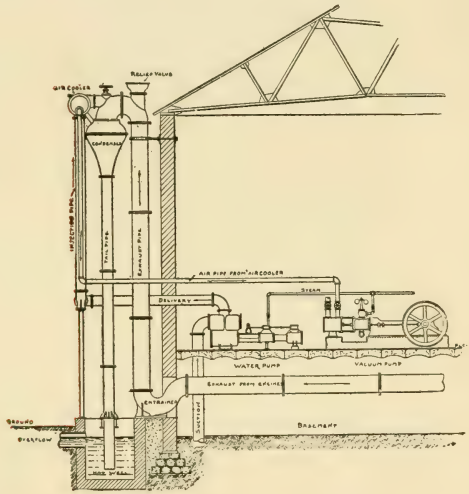
When desired, these condensers can be compounded instead of twinned, and the exhaust from them either condensed in itself or used for auxiliary feed water heating.

Table of Standard Sizes and Dimensions.
Vertical "Twin" Beam Air Pump and Jet Condensers.
(In inches unless otherwise stated.)

Diameter of Steam Cylinders.	Diameter of Water Cylinders.	Length of Stroke.	Sizes of Pipes.					Approximate Over all Dimensions, Including Condenser, in Feet and Inches.		
			Steam Pipe of Pump.	Exhaust Pipe of Pump.	Discharge Opening.	Injection Opening.	Exhaust Inlet.	Height.	Width.	Length.
7½	15	10	1½	2	6	5	8	5-9	3-11	4-6
7½	16½	10	1½	2	7	6	8	5-9	3-11	4-6
9	18	12	2	2½	8	6	10	8-3	4-8	5-4
9	20	12	2	2½	8	7	12	8-3	4-8	5-4
10	22	15	2	2½	10	7	14	8-4	4-9	5-6
12	25	18	2½	3	12	8	18	9-11	5-6	6-2
12	28	18	2½	3	12	10	20	10-2	5-7	6-4
12	30	18	2½	3	14	10	22	10-3	5-10	6-4
14	32	21	2½	3	14	10	24	11-8	7-1	7-4
16	32	21	3	4	14	10	24	11-8	7-1	7-4
14	35	21	2½	3	16	12	24	11-9	7-1	7-4
16	35	21	3	4	16	12	24	11 9	7-1	7-4
14	38	21	2½	3	18	12	24	12 5	7-5	8-8
18	44	24	3	4	20	14	30	14-4	8-9	9-0
16	40	24	3	4	18	12	28	13-6	7-9	8-11
18	48	24	3	4	22	16	36	14 10	9 9	10-10
16	38	21	3	4	18	12	24	12-5	7-5	8-8
16	40	21	3	4	18	12	28	12-6	7 9	8-11
16	44	24	3	4	20	14	30	14-4	8-9	9-10
16	48	24	3	4	22	16	36	14-10	9-0	10-10

Note.—These tables are simply approximate, and are to be used for estimating purposes for preliminary work only. The details of the apparatus are necessarily changed from time to time to keep abreast of the latest ideas and improvements. Therefore detailed drawings should be obtained in each case from the builder for the purpose of laying out and installation.

WORTHINGTON "BAROMETRIC" OR ELEVATED JET CONDENSER.



This type of condenser is often termed a "Central Condenser," because it is frequently used in central stations, one outfit receiving and condensing the exhaust from a number of different engines. At the same time, it is a very efficient and satisfactory type of condenser for a single engine of large size.

A characteristic of the system is the use of separate water and vacuum pumps.

The water pump simply handles the water for condensation, which it lifts by suction and discharges into the condenser cone. The condenser is placed in an elevated position about thirty feet above the hot well, and the water falls out of it by gravity, producing a partial vacuum. This pump, having a uniform duty to perform, is often provided with compound or triple expansion steam cylinders,—or, in the

Worthington "Barometric" Condensers, Concluded.

case of an electric power plant, it may be a motor driven vertical triplex pump.

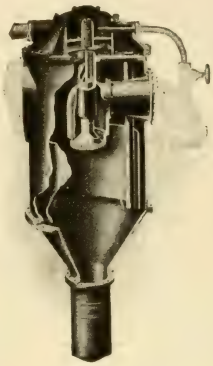
In the condenser cone and air cooler the method of distributing the injection water in the condensing chamber is briefly as follows: The end of the spray pipe is provided with teeth spread to allow the water to pass in sheets edgewise to the incoming steam. The spray cone at the lower end of the spray pipe also tends to break the water up into fine particles. In case foreign material accumulates in the spray nozzle, it can be readily removed by lowering the spray cone by means of the hand wheel on top of the condenser, without interfering with its operation.

The falling of the water in the cone entraps a portion of the air set free by the condensation of the steam, and carries it down into the tail pipe, so that a partial vacuum is formed in the condenser and exhaust piping. In order, however, to obtain a high range of vacuum without using an abnormal amount of water to carry off the air, the separate dry vacuum pump is used. The air not carried off by the water is taken from the empty space under the spray cone in the condenser. This air has a temperature somewhat lower than the temperature of steam, but on passing through the tubes of the air cooler it is cooled by the injection water which flows on the other side of the tubes, to a temperature practically the same as that of the injection water; thus when it reaches the vacuum pump it is reduced in volume and is in the most favorable condition for compression and discharging against the atmosphere.

The duty of the vacuum pump is to exhaust the air from the condenser and the pipe system. As the water pump is assisted in lifting the water by the vacuum in the condenser, it is readily primed and started up and the load on the pump reduced in proportion to this benefit on regular work.

The outline drawing on page 586 shows a general arrangement for the condenser pumps and piping. No table of dimensions can be given, as it will be readily seen that this type of condenser must be designed and built for each special condition.

ALBERGER "BAROMETRIC" CONDENSER.



Sectional View

The foregoing description of the Worthington barometric condenser in many respects also applies to this one, as the apparatus made by both companies is nearly enough alike to be readily understood without further explanation.

The above cuts illustrate the barometric condenser built by the Alberger Condenser Company.

SURFACE CONDENSERS.

In the jet condenser, as already explained, a "jet" or "spray" of cold water condenses the exhaust steam by coming into intimate contact with it. In the surface condenser the result is obtained without commingling the exhaust steam and the injection water. The condensed water is removed from the apparatus by an air or vacuum pump, and delivered to the hot well to be again supplied to the boilers by a feed pump. Not quite all the water can be returned, but the loss is slight, only three to five per cent. This type of condensing apparatus consists of the surface condenser proper, an air (vacuum) pump, and circulating water pump either separate or in combination with it. The pumps may be either separate or consolidated into one complete machine with the condenser.

Worthington Surface Condensers with Combined Air and Circulating Pumps.

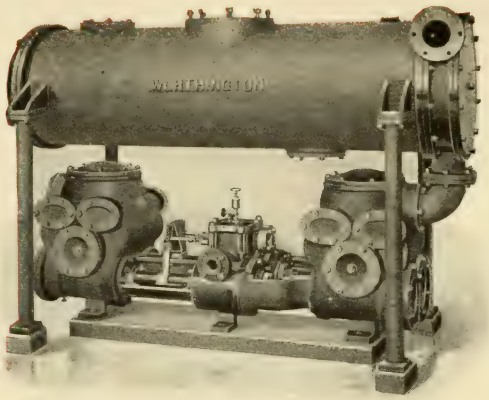
Such a combination forms a complete and very compact apparatus, as will be seen from the cut on the next page. The surface condenser is placed directly over the air and circulating pump; is supported by four substantial cast-iron columns, and is connected to the pump by the necessary pipes. All that remains to be done is to make the steam and water connections to the apparatus.

They are of close grain cast iron and provided with suitable openings for the exhaust steam inlet: connection to the air pump, and also with properly placed openings for cleaning purposes. Suitable feet form a substantial support either upon brick piers or upon girders or columns. The bonnets are provided with hand holes for cleaning or inspection.

The tubes are seamless drawn brass of the very best composition for the purpose. The tube heads are iron or brass, as may be desired, carefully drilled and tapped to receive the followers on one end of the condenser and the screw glands on the other.

One end of each tube is flanged and rigidly held in the tube head by means of a screw follower; the other end of the tube passes through an adjustable gland, which permits of free movement of the tube during expansion and contraction. The glands can be readily removed and the packing replaced if it becomes leaky from long use.

Each condenser is provided with a baffle plate to distribute the exhaust steam as it enters, and the larger sizes have supporting plates to bear the weight of the tubes at the center.



Worthington Surface Condenser with Combined Air and Circulating Pump.

The circulating pump may be of the ordinary steam driven type, vertical or horizontal, with either simple, compound, or triple expansion steam cylinders, or it may be a centrifugal pump, or a triplex pump.

The vacuum pump may also be either of these types, except, of course, not of the centrifugal type. From the variety of types of pumps, both vacuum and circulating, in use for this purpose, it is manifestly out of the question to describe and give details regarding all of them. Therefore this article is of necessity restricted to a consideration of the most common and convenient type in use, viz., the combined air and circulating pump.

This combination, in which one steam end drives both pumps, is an especially good form, if care is taken in the selection of the relative proportions of the cylinders. The steam cylinders may be either single, compound, or triple, as the case may warrant. The cylinders for the circulation of the water are of the same construction as those of standard Worthington pumps, their function being to supply the water used for cooling the surface of the condensers. The steam pistons driving them are located in the central cylinders, the piston rods being prolonged through to the air pumps at their other ends, thus making a direct and simple connection.

By an arrangement of the connecting casting between the circulating and steam cylinders, the steam pistons can be overhauled without disturbing the alignment of the pump or breaking any of the steam or water pipe connections.

Table of Sizes, Dimensions, Etc.

Worthington Surface Condensers, with Combined Air and Circulating Pumps, Concluded.

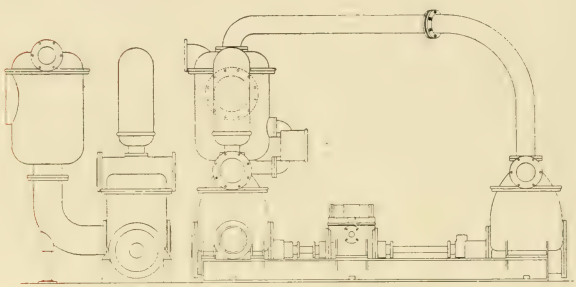
(In inches unless otherwise stated.)

Diameter of Steam Cylinders.	Diameter of Air Pump Cylinders.	Diameter of Circulating Cylinders.	Length of Stroke.	Sizes of Pipes.					Over all Dimensions In Feet and Inches.			Square Feet of Surface in Condenser.
				Steam Pipe.	Exhaust Pipe.	Circulating Pump Suction Pipe.	Circulating Pump Discharge Pipe.	Air Pump Suction Pipe.	Air Pump Discharge Pipe.	Length.	Width.	Height, Including Condenser.	
5½	4¾	4¾	5	¾	1¼	3	2	3	2	6– 9	1–10	3– 4	100
6	5¼	5¾	6	1	1½	4	3	4	3	9– 6	2– 3	4– 2	200
6	5½	5½	6	1	1¾	6	5	6	5	9– 7	2–10	4–10	300
7	6½	6½	6	1½	2	6	5	6	5	9– 9	2–11	5– 0	500
7½	7	7	10	1½	2	6	5	6	5	11–10	3– 1	5– 9	500
7½	7	7¼	10	1½	2	6	5	6	5	12–10	3– 1	6– 3	600
8	7½	8½	10	1½	2	8	5	8	5	13– 0	3– 8	7– 2	800–1000
9	8½	10¼	10	2	2½	10	7	10	7	12– 8	4– 6	8– 1	1200–1400
10	10¼	12	10	2	2½	12	10	12	8	12– 9	4– 6	8– 4	1600–1800
12	11	14	10	2½	2½	12	10	..	10	15– 6	5– 1	8–11	2000
12	15	15	10	2½	3	12	10	..	..	16– 3	5– 6	10– 3	2400
12	15	15	15	2½	3	12	12	..	..	15– 5	6– 5	11– 5	2800–3200
14	17	17	15	2½	3	14	12	..	..	15– 6	6– 7	12– 8	3600–4000
14	19	19	15	2½	3½	14	12	..	..				4500–5000
17	22	22	15	2½	3½	16	14	..	..				

Note.—These tables are simply approximate, and are to be used for estimating purposes for preliminary work only. The details of the apparatus are necessarily changed from time to time to keep abreast of the latest ideas and improvements. Therefore detailed drawings should be obtained in each case from the builder for the purpose of laying out and installation.

It must be remembered, in comparing these sizes with single cylinder air and circulating pumps, that the Worthington has two circulating pistons, and two air pump pistons, all double acting and working together, and is, therefore, double the capacity of a single air and circulating pump with cylinders of like diameter.

DEANE COMBINED SINGLE VACUUM AND CIRCULATING PUMPS.



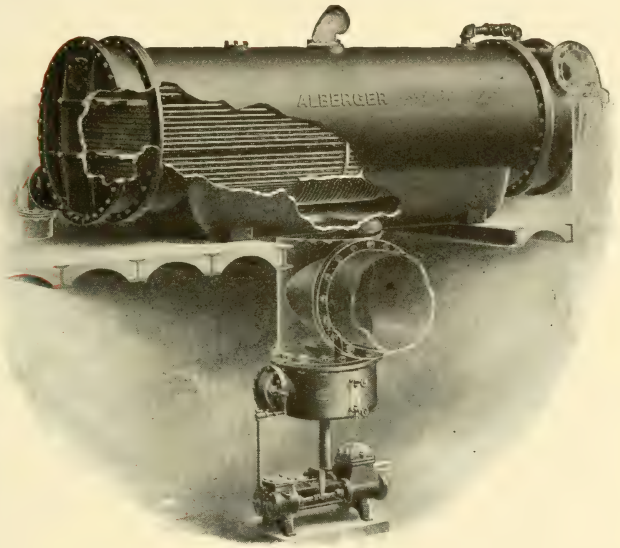
END ELEVATION. SIDE ELEVATION.

(Combined Single Acting Vacuum and Circulating Pump, with Jet Condenser, for use with Cooling Tower.)

Table of Standard Sizes.

Size.					Pipe Sizes.					
Diam. of Steam Cyl.	Diam. of Vacuum Cylinder.	Diam. of Water Cyl.	Length of Stroke.	Gals. circulat'g water per min. at av'ge speed.	Steam.	Exhaust.	Vacuum Pump Suction.	Vacuum Pump Discharge.	Circulating Pump Suction.	Circulating Pump Discharge.
6	6	6	7	74	¾	1	3	3	4	4
5½	5½	7½	7	115	¾	1	3	3	5	5
6	6	8	7	131	¾	1	3	3	5	5
6	7	7	10	140	¾	1	4	4	5	5
7½	7½	7½	10	160	1	1½	4	4	5	5
6	7	9	10	231	¾	1	4	4	6	6
7½	7½	9½	10	258	1	1½	4	4	6	6
8	8	8	12	209	1	1½	4	4	5	5
8	9	9	12	264	1	1½	4	4	6	6
8	8	10	12	326	1	1½	4	4	8	8
8	10	10	12	326	1	1½	6	6	8	8
10	10	10	12	326	1½	2	6	6	8	8
8	9	11	12	395	1	1½	6	6	8	8
8	10	12	12	470	1	1½	6	6	8	8
10	10	12	12	470	1½	2	6	6	8	8
10	12	12	12	470	1½	2	6	6	8	8
10	12	14	12	640	1½	2	6	6	10	10
10	14	14	12	640	1½	2	6	6	10	10
10	14	16	12	836	1½	2	6	6	10	10
12	14	14	18	799	2	2½	8	10	9	8
14	14	16	18	1044	2	2½	8	10	12	8
16	16	18	18	1322	2	2½	8	10	12	8
16	18	20	18	1630	2	2½	8	14	16	10
16	18	20	24	1975	2	2½	10	14	16	10
18	20	22	24	2370	3	3½	10	16	18	10
18	20	24	24	2820	3	3½	10	18	20	10
18	22	24	24	2820	3	3½	12	18	20	12

ALBERGER COUNTER-CURRENT SURFACE CONDENSER.

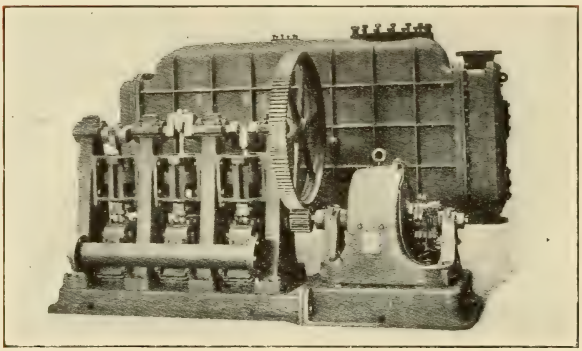


(The above cut shows a condensing system developed by the Alberger Company especially for steam turbine work that is unique in a number of respects.)

The usual form of surface condenser, as shown on pages 589 and 594—597 operates under what is termed "the wet system,"—in which the exhaust steam enters the condenser at the top, and the water of condensation and air resulting from the condensation are removed by a wet vacuum pump.

This Alberger surface condenser above shown operates under what is termed "the dry system,"—the exhaust steam entering at the bottom of the condenser and the water of condensation falling back against the incoming steam, being thereby heated up and removed by a hot well pump, all as shown. The air remaining after the condensation of the steam is removed by a dry vacuum pump just after it has been in contact with the tubes containing the coldest water. This effect is accomplished by bringing in the cooling water at the top of the condenser and removing it at the bottom.

WHEELER SURFACE CONDENSERS.



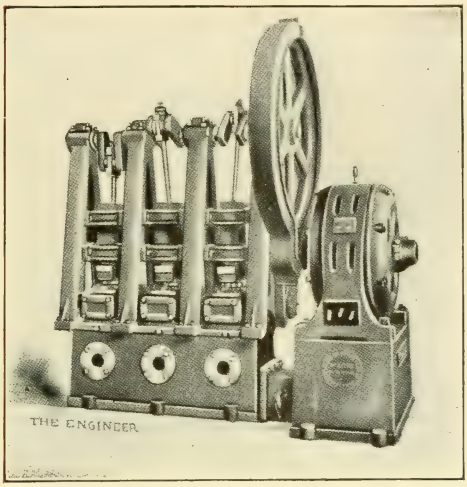
(1500 H. P. Wheeler-Admiralty Surface Condenser, with Edwards Triplex Air Pump driven by direct connected D. C. Electric Motor, for installation in connection with a turbine outfit. The circulating pump is not shown in this cut.)

The Wheeler Company makes a specialty of condensing apparatus for steam turbine work. As shown on pages 926 and 927, they are furnishing the condensing machinery to the Lane Mills, in New Orleans, operating in conjunction with three 500 K. W. Curtis turbines.

Steam turbine practice requires a high vacuum to secure the best results, and the problem therefore is to design an apparatus that will maintain a vacuum of not less than 28 inches under normal full load conditions.

The Wheeler apparatus consists of their "Admiralty" rectangular pattern surface condenser, and Edwards air pump of the triplex type either steam driven or electrically driven, and a circulating pump of the centrifugal type either steam or electrically driven, all as shown on page 595, where the pumps are electrically driven, and on pages 926-927 where they are steam driven. When motor driven, the motor may be either of the direct current type or the induction alternating current type.

Wheeler Surface Condensers, Continued.



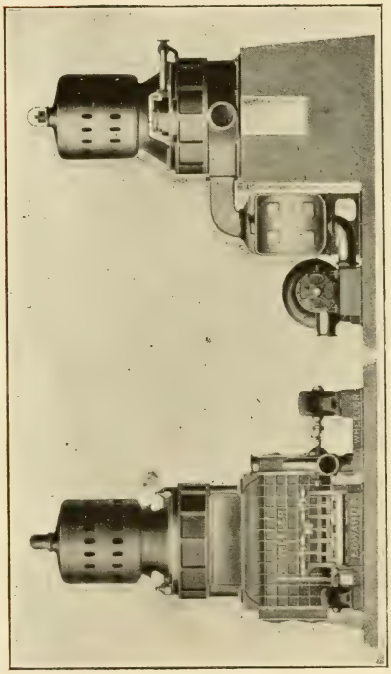
(The above cut shows an Edwards Air Pump of the Triplex Type driven by a direct connected A. C. Induction Motor.)

One of the peculiarities of the Edwards air pump is the elimination of the foot valves, giving this type of pump an advantage, it is claimed, of from one-half to one inch vacuum; the only valves used are those which in the ordinary type of pump are termed "head valves,"—but which in this pump are simply termed "the valves."

The construction of the pump is such that the condensed steam flows continuously by gravity from the condenser into the base of the pump where it is handled by the bucket, which has a conically shaped bottom made to fit the bottom of similar shape. Upon the descent of the bucket the water is quietly and without shock projected at high velocity through the ports into the working barrel. The rising water is followed by the rising bucket which closes the ports and sweeps the air and water before it, discharging them through the valve at the top of the barrel.

The speed of the water corresponds to the speed of the bucket, and consequently this type of pump is specially adapted to high speeds and an increase of speed does not impair its efficiency.

Wheeler Surface Condensers, Concluded.



The above cut shows the general arrangement of the Wheeler condensing apparatus with electrically driven pumps, installed at the Newport Station of the Old Colony Street Railway Company, Newport, R. I.

The advantages claimed for this apparatus are:

"The Edwards air pump is especially adapted to obtaining the high vacuum required, dispensing with suction valves, which in turn increases the vacuum from ½ inch to 1 inch above that obtained with the ordinary air pump fitted with suction valves. The arrangement of the three cylinders and separate connections insures proper draining of the water of condensation from the condenser and the extraction of all the air contained in feed water.

"This arrangement reduces the apparatus to a minimum, dispensing with wet and dry air pumps, air coolers, etc., and at the same time gives as high a result as can be obtained with the above multiplicity of apparatus, thus saving first cost, space, and minimizing the cost of operation and repairs."

Surface Condensers, Concluded.

Determination of Amount of Circulating Water, Etc.

The formula to be used in connection with surface condensers does not differ greatly from that given on page 581 for jet condensers.

The modification is as follows:

$$Q=\frac{1190-Ta}{T-t}$$

Q=Pounds of water required to condense one pound of steam.

Ta=Temperature of air pump discharge, degrees F.

T=Final temperature of circulating water, degrees F.

t=Initial temperature of circulating water, degrees F. This is generally assumed to be 15° less than the temperature corresponding to the vacuum desired.

The rule is to subtract the temperature of the air pump discharge from 1190 and divide the difference by the rise in temperature of the circulating water, all in degrees Fahrenheit.

For Amount of Condensing Surface required:

The rule is for 70 degrees initial temperature of circulating water and 26 inches vacuum, to figure one square foot of surface for each ten pounds of steam to be condensed.

The list of standard apparatus on page 591 shows the proper size of pump for each size of condenser.

See pages 598-'9.

Steam Data for Condenser Calculations.

Physical Properties of Steam.

Pressure.		Temperature.	Heat Required to Convert a Pound of Water at Zero F. into Steam.		
Vacuum by Gauge. Inches Mercury.	Absolute. Pounds per Square Inch.	Degrees F.	To Raise the Temperature to the Boiling Point. Heat Units.	To Convert the Water at the Boiling Point into Steam. Heat Units.	Total. Heat Units.
29.74	.089	32	32	1091 700	1123.700
29.72	.100	35	35	1089.615	1124.615
29.67	.122	40	40.001	1086.139	1126.140
29.62	.147	45	45.002	1082.663	1127.665
29.56	.176	50	50.003	1079.187	1129.190
29.49	.212	55	55 006	1075.709	1130.715
29.40	.254	60	60.009	1072.231	1132 240
29.30	.302	65	65.014	1068.751	1133 765
29.19	.359	70	70.020	1065.270	1135 290
29	.425	75	75.027	1061.788	1136.815
28.90	.502	80	80.036	1058.304	1138.340
28.72	.590	85	85.045	1054.800	1139 865
28.51	.692	90	90.055	1051.355	1141.390
28.27	.809	95	95.065	1047.850	1142.915
28	.943	100	100 080	1044.360	1144.440
27.89	1.	102	102.086	1042.964	1145.050
27.69	1.094	105	105.095	1040 870	1145.965
27.34	1.265	110	110.110	1037 380	1147.490
27	1.435	114.34	114.470	1034.344	1148.814
26.95	1.462	115	115.129	1033.886	1149.015
26.50	1 682	120	120.149	1030.391	1150 540
26	1.931	125	125.169	1026.896	1152.065
25.85	2.	126.266	126.440	1026.010	1152.450
25.42	2.213	130	130.192	1023.389	1153.590
25	2.417	133	133.21	1021.295	1154.505
24.79	2.526	135	135.217	1019 898	1155 115
24.06	2.876	140	140 245	1016.395	1156.640
24	2.9	141.293	141 543	1015.491	1157.034
23.81	3.	141.622	141 877	1015.254	1157 131
23 26	3.270	145	145 275	1012.890	1158.165
23	3 399	146.528	146.808	1011.823	1158 631
22.37	3 707	150	150.305	1009 385	1159.690
22	3 9	152.05	152 37	1007.945	1160.315
21 78	4.	153.670	153 396	1007.229	1160.625
21 39	4.191	155	155.339	1005.876	1161.215
21	4 373	156.74	157.09	1004 452	1161.542
20.29	4 729	160	160.374	1002.366	1162.740
20	4.863	161.63	161.543	1001.552	1163.095
19.74	5.	162 33	162.722	1000.727	1163.449
19.08	5.324	165	165 413	998.852	1164.265
19	5.36	165.317	165.730	998.632	1164.362
18	5.855	169	169.45	996.035	1165.485
17.74	5 981	170	170.453	995.337	1165.790
17.71	6.	170.123	170.577	995 249	1165.826
17	6.346	172.6	173 07	993.513	1166.583
16.27	6.704	175	175.497	991.818	1167.315
16	6.837	175.9	176.4	991.180	1167.580
15.67	7.	176.910	177.425	990.471	1167 896
15	7.329	178.98	179.51	989.019	1168.529

See pages 607-610.

Steam Data, Concluded.

Physical Properties of Steam, Concluded.

Pressure.		Temperature.	Heat Required to Convert a Pound of Water at Zero F. into Steam.		
Vacuum by Gauge. Inches Mercury.	Absolute. Pounds per Square Inch.	Degrees F.	To Raise the Temperature to the Boiling Point. Heat Units.	To Convert the Water at the Boiling Point into Steam. Heat Units.	Total. Heat Units.
6	11.7	200 747	201.514	973.654	1175.168
5 49	12	201 960	202.737	972.800	1175 537
5	12.24	202 924	203.712	972.120	1175.832
4	12.73	204.772	205.58	970.815	1176 395
3.93	12.766	205	205.813	970.652	1176.465
3.45	13	205.885	206.709	970.025	1176 734
3	13 222	206.722	207.557	969.433	1176.99
2	13.714	208.522	209 377	968.162	1177.539
1.42	14	209 560	210.428	967.427	1177.855
1.17	14.122	210	210.874	967.116	1177.990
1	14.205	210.3	211.17	966.9115	1178.0815
	14.696	212	212.900	965.700	1178.600
Gauge Pressure lbs. per sq. inch.					
.304	15	213 025	213.939	964.973	1178.912
1.304	16	216.296	217.252	962.657	1179.909
2 304	17	219 410	220.409	960.450	1180.859
3.304	18	222.378	223.419	958.345	1181.764
4.304	19	225.203	226.285	956.343	1182.628
5.304	20	227.917	229 009	954.405	1183.454
6.304	21	230.515	231.676	952.570	1184.246
7.304	22	233 017	234 218	950.791	1185.009
8.304	23	235 432	236 672	949 072	1185.744
9.304	24	237.752	239 029	947.424	1186 453
10.304	25	240.000	241.314	945.825	1187.139
11.304	26	242.175	243.526	944.277	1187.803
12.304	27	244.284	245.671	942.775	1188.446
13.304	28	246.326	247.748	941.321	1189.069
14.304	29	248.310	249.769	939.905	1189 674
15.304	30	250.245	251.738	938.925	1190.268
14.65	7.500	180	180.542	988.298	1168.840
14	7.82	181.877	182.427	986 980	1169.407
13.63	8	182.910	183.481	986.245	1169.726
13	8.311	184.668	185.25	985.014	1170.264
12.87	8.375	185	185.591	984.774	1170.365
12	8.802	187.272	187.885	983.360	1171.245
11.60	9	188.316	188.941	982.434	1171 375
11	9.293	189 82	190.46	981.375	1171.835
10.92	9.33	190	190 643	981.247	1171.890
10	9.784	192.21	192.89	979 674	1172.564
9.56	10	193.240	193.919	978.958	1172.877
9	10.275	194.53	195.22	978.052	1173.272
8.79	10.38	195	195.697	977.718	1173.415
8	10.767	196.742	197.46	976.480	1173.946
7.53	11	197 768	198.496	975.762	1174.258
7	11.258	198.9	199.64	974.964	1174.604
6.46	11.52	200	200.753	974.187	1174 940

See pages 607-610.

SELF-COOLING CONDENSERS—COOLING TOWERS.

Where water for condensing purposes can not readily be obtained by damming some local stream or drawing direct from an adjacent river, the usual method in the past has been to put in a reservoir for the purpose large enough to be self-cooling by evaporation; such a reservoir is not only expensive in first cost, but it seldom pays to build the reservoir large enough to keep the temperature of the water as low as is really desirable.

The modern cooling tower is adaptable to all locations, and easily meets and overcomes the difficulties of any situation. The only cost in connection with it is the comparatively small one of operating the fan and a slight expense in the way of pumping for the occasional renewal of the water lost by evaporation,—even this, however, becomes practically eliminated by the gain due to the water condensed from the steam.

There is no question but that cooling towers possess certain advantages over even natural sources of water supply, such as rivers and ponds: for instance, the water supply is not liable to be cut off from the condenser by ice or other foreign materials, nor the suction lost on account of low water; and the durability of the condenser is enhanced by the freedom of the water from sand and other material that wear the moving parts, and by the partial lubrication the machine receives from the slight amount of oil coming from the cylinders of the main engine.

As to the benefits to be derived from condensing, it is hardly worth while to more than call attention to the fact that any engine running non-condensing labors under a back pressure of 14.7 pounds (caused by exhausting against the atmosphere), the greater part of which can be removed by exhausting into a partial vacuum. The percentage gained by condensing varies very greatly, but will seldom run below 12½ per cent., even on single cylinder engines. In the installation of new plants, compound condensing engines can be used with a resulting steam economy thirty to fifty per cent. greater than was ever possible with single cylinder non-condensing engines.

The cooling tower depends for its effectiveness upon the capacity of atmospheric air to absorb and carry off heat and moisture. Broadly considered, the air becomes the condensing medium in the place of cold water as ordinarily employed, and on account of its general distribution the process can be performed at any place desired. When properly manipulated, as in the apparatus under consideration,

Cooling Towers, Continued.

air becomes a better medium for condensation than water, not only on account of its pre-eminent abundance, but because of its freedom from foreign materials.

Cooling towers may be generally stated as of two types—

(1). Those in which the air is circulated by means of one or more fans, which is the type ordinarily recommended.

(2). Those in which a suitable draft is secured by means of a stack placed above the cooling tower proper.

Worthington Cooling Towers.

The complete self-cooling outfit consists of two parts—the condenser in which the exhaust steam of the main engine, or engines, is condensed, and the tower in which the heated discharge water from the condenser is cooled to proper temperature, to be used again in the condenser for the further condensation of the exhaust steam.

The tower consists of a cylindrical steel shell, open at the top; supported upon a suitable foundation, and having fitted at one side a fan, the function of which is to circulate a current of air up through the tower and its filling. This filling consists of layers of cylindrical tubular tiling, which rests upon a grating supported by a brick wall extending around the circumference of the tower. The heated discharge water from the condenser enters the tower at the side, passes up the central pipe, is delivered on the upper layer of tiling and over the whole cross-section of the tower by a distributing device consisting of four pipes, which are caused to rotate about the central water pipe by the simple reaction of the jets of heated water issuing from one side of each pipe after the manner of a Barker's mill. The water thus delivered spreads over the outside and inside surfaces of the walls of the tiling, and forms a continuous sheet which is presented to the action of the air. The tiling is placed on end in horizontal layers, one upon the other, and packed as closely as possible, the walls of each individual tile of each successive layer being disposed so as to come opposite the air spaces of the next lower layer, breaking joints, as it were, the object being in this disposition to break up both the currents of air and water so that the most thorough and extended contact will take place. If there are ten layers of tiling in a tower, then there are nine places, in addition to the original spreading at the top, at which there is a com-

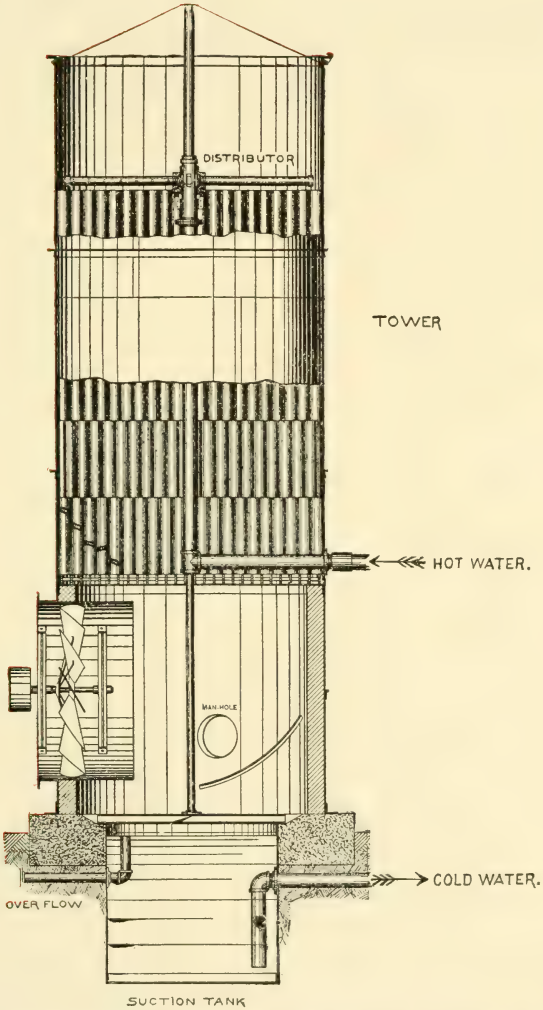
Worthington Cooling Towers, Continued.

plete redistribution of the water. It will be seen that each tile must rest on at least two, and possibly three, in the next lower layer. Assuming, however, that each tile rests on only two others, a given quantity of water, placed on any one tile in the top layer, will be divided over at least two tiles in the second layer, three in the third, four in the fourth, and so on, until it becomes spread over fifty-four in the lowest layer on the grating.

The air is distributed in an equally good manner, and there is a large, free area with equal facility for its passage upward over the entire cross section of the tower. The heated water falling through the tower is cooled by three processes—first, radiation from the sides of the tower: second, the contact of cool air, and third, evaporation. This latter is by far the most important, as the evaporation of a pound of water in this way carries off about 1,000 units of heat, and enables a pound of steam to be condensed in the condenser. As quite a proportion of the cooling is done by the first two processes, the evaporation of water in the tower must be less than the water formed by steam condensed in the condenser. Consequently, the supply of circulating water is constantly augmented and requires but little replenishing. The cooled water falls from the grating to the subsiding tank at the bottom, and is from there drawn by the condenser to perform condensation again.

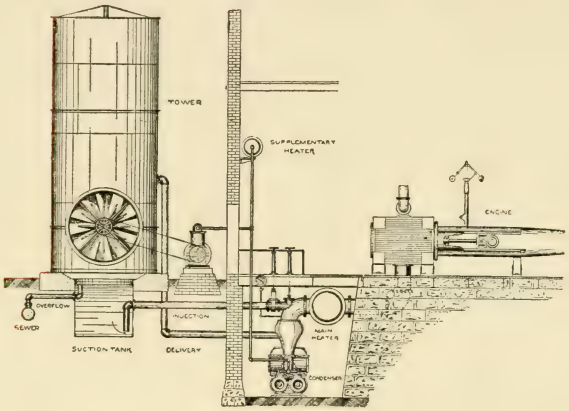
The current of air is passed through the tower by a circulating fan, driven either by a small engine, an electric motor (if a current is available at all times), or by belting from the main engine or line shaft, as the case may be.

In situations where the water is unfit for boiler feeding, is so impure as to form objectionable scale in the boilers, a modification of the apparatus may be used to great advantage. This modification consists in the substitution of a surface condenser, with air and circulating pumps for the jet condenser and pump. The circulating pump draws the cold water from the suction tank, passes it through the tubes of the surface condenser and the tower, and back again in a continuous circuit to the suction tank. The exhaust steam from the main engine brought in contact with the outside of the tubes is condensed. The pure water thus formed, together with the air and condensable vapor, is removed by the air pump and delivered to the hot well, from whence the water is fed to the boilers.

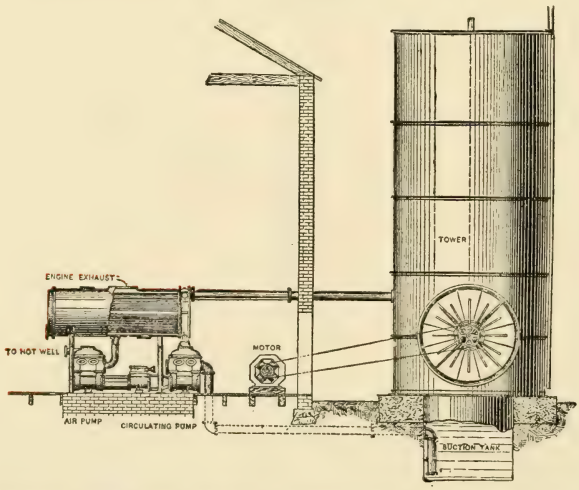


Section Showing Details of Construction and Operation of Worthington "Cooling Tower."

Worthington Cooling Towers, Continued.



Cooling Tower with Jet Condenser, Fan Driven by Small Auxiliary Engine.



Cooling Tower with Surface Condenser and Motor Driven Fan

Worthington Cooling Towers, Concluded.

Table of Sizes, Dimensions, Etc.

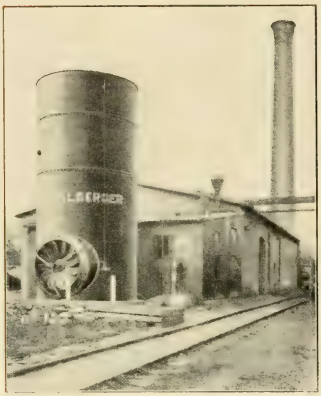
Worthington Self-Cooling Condensers ("Cooling Towers").

Size of Machine.	2-M	3-M	4-M	6-M	8-M	10-M	12-M	16-M	20-M	24-M
Capacity in lbs. steam	2000	3000	4000	6000	8000	10000	12000	16000	20000	24000
Engine H. P., at 20 lbs. water rate	100	150	200	300	400	500	600	800	1000	1200
Diameter of tower (pipe)	4'6"	7'	6'6"	7'6"	8'6"	10'	11'	12'	14'	15'
Diameter of tower (tile)	5'	7'	7'	8'5"	10'	11'	12'	15'	17'	18'
Height of tower (pipe)	19'	20'	20'	21'	22'	23'	24'	24'	25'	26'
Height of tower (tile)	25'	25'	26'	29'	30'	31'	31'	31'	31'	31'
Size of tank	3x6	4x6	5x6	5x7	6x7	7x7	7x7	8x7	9x7	10x7
Gallons in tank	260	470	600	870	1250	1700	1700	2300	2800	3400
Gallons circulated per minute	150	225	300	450	600	750	900	1200	1500	1800
Diameter of fan	36"	48"	54"	60"	72"	84"	96"	96"	108"	120"
Revolutions of fan per minute	760	570	500	500	400	325	300	260	240	230
Horse power to drive fan	2.2	3.9	4.9	7.0	9.0	11.9	13.0	15.0	24.00	30.0
Size of suction pipe	3	3	4	4	5	6	6	6	8	8
Size of discharge pipe	3	4	4	4	6	6	6	8	8	8

Note: These tables are simply approximate, and are to be used for estimating purposes for preliminary work only. The details of the apparatus are necessarily changed from time to time to keep abreast of the latest ideas and improvements. Therefore detailed drawings should be obtained in each case from the builder for the purpose of laying out and installation.

"Capacity in pounds of steam" is the rate per hour of the maximum capacity at any one instant. An outfit includes tower, tank, distributor, fan, fan motor, stringer, gauges, lubricator, all piping in tower, erection of tower. Foundation and piping usually furnished by purchaser.

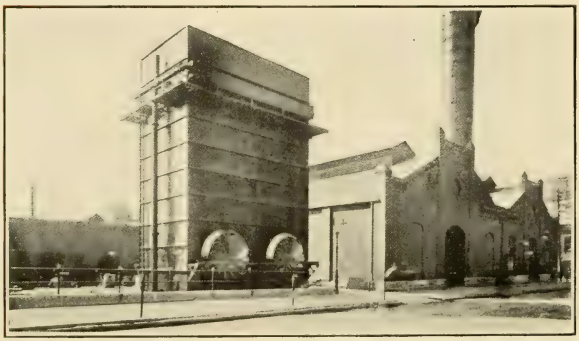
Alberger Cooling Towers.



The Alberger tower is also cylindrical in form, and constructed of sheet steel. The filling consists of boards of swamp cypress geometrically arranged to render every foot of superficial area effective as cooling surface. While at first thought this construction would not seem durable, still the Government Reports contain records of cypress shingles having lasted for a period of sixty to eighty years.

The fans and method of driving them for circulating the air are practically the same as in the Worthington tower.

The Barnard-Wheeler Cooling Tower.



The Barnard-Wheeler tower is of similar design to both the foregoing, except that the tower casing is usually square, and the hot circulating water is distributed in a thin film over the meshes of galvanized wire mats which constitute the filling and take the place of the tiling in the Worthington tower and of the cypress boards in the Alberger tower.

NOTES ON STEAM.

(KENT.)

Absolute Pressure is the gauge pressure plus 14.7, which is atmospheric presssure in pounds per square inch.

Absolute Temperature is the thermometer reading plus 461 (460.66) degrees Fahrenheit, or 273 degrees Centigrade.

The Temperature of Steam in contact with water depends upon the pressure under which it is generated. At the ordinary atmospheric pressure (14.7 pounds per square inch) its temperature is 212 degrees Fahrenheit. As the pressure is increased, as by the steam being generated in a closed vessel, its temperature, and that of the water in its presence, increases.

Saturated Steam is steam of the temperature due to its pressure,—not superheated.

Superheated Steam is steam heated to a temperature above that due to its pressure.

Dry Steam is steam which contains no moisture. It may be either saturated or superheated.

Wet Steam is steam containing intermingled moisture, mist or spray. It has the same temperature as dry saturated steam of the same pressure.

Water introduced into the presence of superheated steam will flash into vapor until the temperature of the steam is reduced to that due to its pressure. Water in the presence of saturated steam has the same temperature as the steam. Should cold water be introduced, lowering the temperature of the whole mass, some of the steam will be condensed, reducing the pressure and temperature of the remainder, until an equilibrium is established.

Temperature and Pressure of Saturated Steam.—The relation between the temperature and the pressure of steam, according to Regnault's experiments, is expressed by the formula (Buchanan's, as given by Clark)

$$t = \frac{2938.16}{6.1993544 - \log p} - 371.85,$$

in which p is the pressure in pounds per square inch and t the temperature of the steam in Fahrenheit degrees. It applies with accuracy between 120 degrees Fahrenheit and 446 degrees Fahrenheit, corresponding to pressures of from 1.68 pounds to 445 pounds per square inch.

Total Heat of Saturated Steam (above 32 degrees Fahrenheit).—According to Regnault's experiments, the formula for total heat of steam is $H = 1091.7 + .305\ (t - 32$ degrees), in which t is temperature Fahrenheit, and H the heat-units. (Rankine and many others; Clark gives 1091.16 instead of 1091.7.)

Notes on Steam, Continued.

Latent Heat of Steam.—The formula for latent heat of steam as given by Rankine and others, is $L=1091.7-.695(t-32 \text{ degrees})$. Clausius's formula in Fahrenheit units, as given by Clark, is $L=1092.6-.708(t-32 \text{ degrees})$.

The total heat in steam (above 32 degrees) includes three elements:

(1). The heat required to raise the temperature of the water to the temperature of the steam.

(2). The heat required to evaporate the water at that temperature, called internal latent heat.

(3). The latent heat of volume, or the external work done by the steam in making room for itself against the pressure of the superincumbent atmosphere (or surrounding steam if enclosed in a vessel).

The sum of the last two elements is called the latent heat of steam.

Heat Required to Generate One Pound of Steam from water at 32 degrees Fahrenheit.

	Heat units.	
Sensible heat, to raise the water from 32 to 212 degrees, =		180.9
Latent heat, 1, of the formation of steam at 212 degrees, =	894.0	
2, of expansion against the atmospheric pressure, 2116.4 lbs. per sq. ft. x 26.36 cu. ft. = 55,786 foot pounds ÷ 778=	71.7	965.7
Total heat above 32 degrees F.		1146.6

The Heat Unit or British Thermal Unit.—The definition of the heat unit used in this work is that of Rankine, accepted by most modern writers, viz., the quantity of heat required to raise the temperature of one pound of water one degree F. at or near its temperature of maximum density (39.1 degrees F.). Peabody's definition, the heat required to raise a pound of water from 62 degrees to 63 degrees F. is not generally accepted.

Relative Volume of Steam.—The relative volume of saturated steam is expressed by the number of volumes of steam produced from one volume of water, the volume of water being measured at the temperature 39 degrees F. The relative volume is found by multiplying the volume in cu. ft. of one pound of steam by the weight of a cu. ft. of water at 39 degrees Fahrenheit, or 62.425 pounds.

Gaseous Steam.—When saturated steam is superheated or surcharged with heat, it advances from the condition of saturation into that of gaseity. The gaseous state is only

Notes on Steam, Continued.

arrived at by considerably elevating the temperature, supposing the pressure remains the same. Steam thus sufficiently superheated is known as gaseous steam or steam gas.

Total Heat of Gaseous Steam.—Regnault found that the total heat of gaseous steam increased, like that of saturated steam, uniformly with the temperature, and at the rate of .475 thermal units per pound for each degree of temperature, under a constant pressure.

Superheated Steam.—The above remarks concerning gaseous steam are taken from Clark's Steam Engine. Wood gives for the total heat (above 32 degrees) of superheated steam $H=1091.7+0.48$ (t—32 degrees).

Commercial Sizes of Anthracite Coal.

Egg coal must pass through 2¾" mesh and not through 2".

Stove coal must pass through 2" mesh and not through 1¼".

Chestnut must pass through 1¼" and not through ¾".

Pea coal must pass through ¾" mesh and not through ½".

Buckwheat No. 1 must pass through ½" mesh and not through ¼".

Buckwheat No. 2 or rice, must pass through ¼" mesh and not through ⅛".

Approximate Heating Value of General Grades of Coal, Per Pound of Combustible B. T. U.

Kind of Coal	Per Cent. of Combustible		Heating Value Per Pound of Combustible
	Fixed Carbon	Volatile Matter	
Anthracite	97.0 to 92.5	3.0 to 7.5	14,600 to 14,800
Semi-Anthracite	92.5 to 87.5	7.5 to 12.5	14,700 to 15,500
Semi-Bituminous	87.5 to 75.	12.5 to 25.	15,500 to 16,000
Bituminous, Eastern	75. to 60.	25. to 40.	14,800 to 15,200
Bituminous, Western	65. to 50.	35. to 50.	13,500 to 14,800
Lignite	Under 50.	Over 50.	11,000 to 13,500

Wood and Coal—Relative Value for Steam Making.

(Dry Woods.)

White Oak weighs	3,850 lbs. per cord	=1,540 lbs. Coal
Poplar and Elm weigh	2,350 lbs. per cord	= 940 lbs. Coal
Southern Pine weighs	3,375 lbs. per cord	=1,300 lbs. Coal
Average Pine weighs	2,000 lbs. per cord	= 800 lbs. Coal

Roughly speaking, one ton of Pocahontas coal=two and a quarter cords of wood.

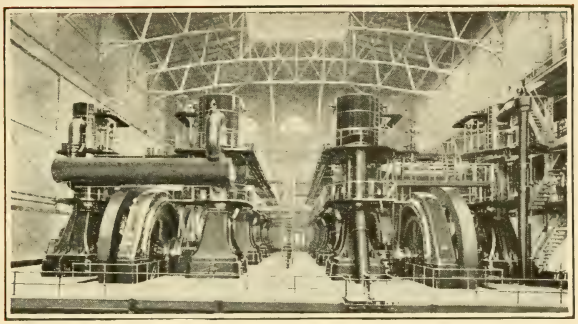
Notes on Steam, Concluded.

*Properties of Saturated Steam.

Absolute Pressure in Pounds per Square Inch	Temperature F.	Cubic Feet in One Pound.	Weight of One Cubic Foot.	Relative Volume to Same Weight Water.	Heat of Liquid above 32° Fahr. B. T. U.	Latent Heat above 32° Fahr. B. T. U.	Total Heat above 32° Fahr. B. T. U.	Absolute Pressure in Pounds, per Square Inch.
30	250.2	13.46	.0742	840	219.7	938.9	1158.6	30
31	252.1	13.05	.0765	815	221.6	937.2	1158.8	31
32	253.9	12.67	.0789	791	223.5	935.9	1159.4	32
33	255.7	12.31	.0812	768	225.3	934.6	1159.9	33
34	257.4	11.97	.0835	747	227.1	933.4	1160.5	34
35	259.1	11.65	.0858	727	228.8	932.2	1161.0	35
40	267.	10.26	.0974	640	236.9	926.5	1163.4	40
45	274.	9.19	.1087	574	244.3	921.3	1165.6	45
50	281.	8.32	.1200	519	251.0	916.6	1167.6	50
55	287.	7.61	.1313	475	257.2	912.3	1169.4	55
60	292.	7.01	.1425	438	262.9	908.2	1171.2	60
65	298.	6.50	.1537	406	268.3	904.5	1172.8	65
70	303.	6.06	.1648	378	273.4	900.9	1174.3	70
75	307.	5.68	.1759	355	278.2	897.5	1 75.7	75
80	312.	5.34	.1871	333	282.7	894.3	1177.0	80
85	316.	5.05	.1978	315	287.0	891.3	1178.3	85
90	320.	4.79	.2088	298	291.2	888.4	1179.6	90
95	324.	4.55	.2197	284	295.1	885.6	1180.7	95
100	327.	4.33	.2305	271	298.9	882.9	1181.8	100
105	331.	4.14	.2414	258	302.6	880.3	1182.9	105
110	334.	3.96	.2522	247	306.1	877.9	1184.0	110
115	338.	3.80	.2630	237	309.5	875.5	1185.0	115
120	341.	3.65	.2737	228	312.8	873.2	1185.9	120
125	344.	3.51	.2845	219	316.0	870.9	1186.9	125
130	347.	3.39	.295	211	319.1	868 7	1187.8	130
135	350.	3.27	.3058	204	322.1	866.6	1188.7	135
140	353.	3.16	.3165	197	325.0	864.6	1189.5	140
145	356.	3 06	.3271	191	327.8	862.6	1190.4	145
150	358.	2.96	.3376	185	330.6	860.6	1191.2	150
155	361.	2.87	.3482	179	333.2	858.7	1192.0	155
160	363.	2.79	.3587	174	335.9	856.9	1192.7	160
165	366.	2.71	.3694	169	338.4	855.1	1193.5	165
170	368.	2.63	.3798	164	340.9	853.3	1194.2	170
175	370.	2.56	.3904	160	343.4	851.6	1194.9	175
180	373.	2.49	. 009	156	345.8	849.9	1195.7	180
185	375.	2.43	.4114	152	348.1	848.2	1196.3	185
190	377.	2.37	.4218	148	350.4	846.6	1197.0	190
195	379.	2.31	.4323	144	352.7	845.0	1197.7	195
200	381.	2.26	.4427	141	354.9	843.4	1198.3	200
205	383.	2.20	.4536	138	357.1	841.9	1199.0	205
210	385.	2.16	.4636	135	359.2	840.4	1199.6	210
215	387.	2.11	.4739	132	361.3	838.9	1200.2	215

*Concluded from pages 598-9. On page 599 the last seventeen lines should be at top of page.

CORLISS ENGINES.



(Kingsbridge Power Station of the Metropolitan Street Railway, New York City, showing Westinghouse Corliss Compound Engine units aggregating 40,000 horse power.)

Types of Engines.

To meet all the requirements of modern practice, Corliss engines are built both **horizontal and vertical** and for either single, double, triple, or quadruple expansion.

Both **simple and compound engines** can be run either **condensing or non-condensing.**

Simple engines are built either with single cylinders, or twinned with two high pressure cylinders.

Compound engines are arranged either as cross compound, tandem compound, or twin tandem compound.

Two general types of horizontal engines are made:

Girder Frame Engines, which are adapted to ordinary work, with steam pressures that should not as a rule exceed 100 pounds.

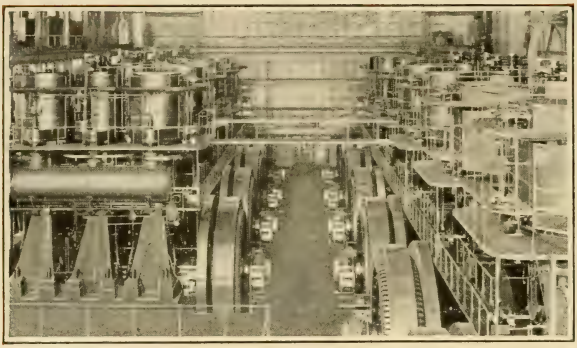
The Heavy Duty Type, which is adapted to the most exacting service and the use of the highest pressures. It may now be said to be the standard type of cotton mill engine.

This type may in turn be divided into two classes, viz.,

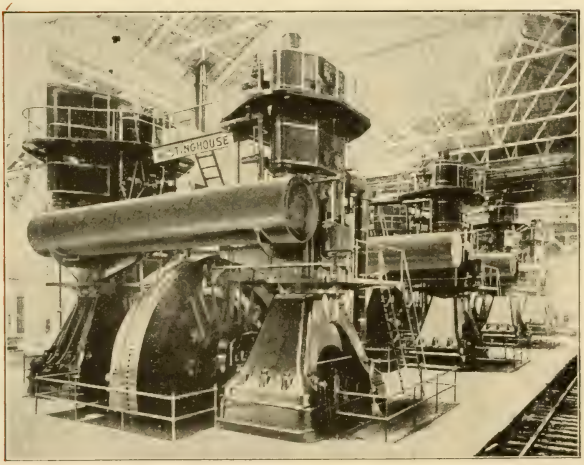
(1). Those for **direct connection to generators**, for electric power or lighting.

(2). Those with **wheels for belt or rope transmission.**

Corliss Engines, Continued.

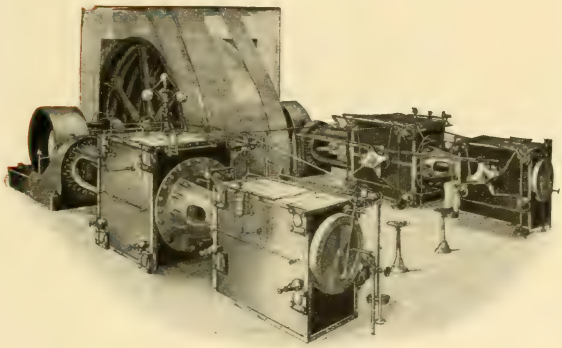


(Electric Light Station of the New York Edison Co., New York City, showing Westinghouse 3-Cylinder Vertical Cross Compound Engine units, aggregating 75,000 H. P.)



(Main Service Plant of the Louisiana Purchase Exposition, St. Louis, Mo., showing Westinghouse Vertical Cross Compound Corliss Engine unit, aggregating 12,000 H. P.)

Corliss Engines, Continued.



(2,000 H. F. Twin Tandem Compound Condensing Engine.)

Engines Arranged to Double Up by the Addition of Another Side.

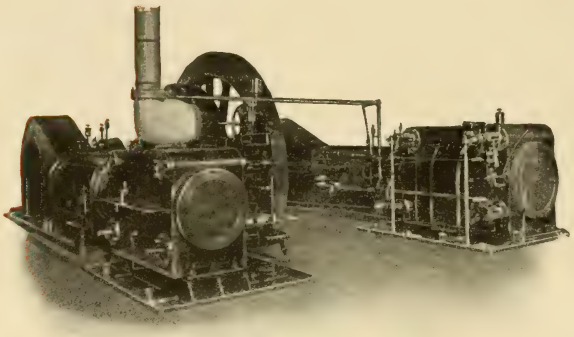
The above cut illustrates a Corliss engine installed in a large New England cotton mill. The wheel is 22 feet in diameter by 11 feet 6 inches face, and is crowned for four belts, one to drive to each floor.

This type of engine is peculiarly adapted for installation in a cotton mill where one-half of it is to be built and started up several years before the other half is to be added.

In such a case it is seen that the one side of this engine which would be installed in the beginning is a complete tandem compound condensing engine,—showing all the economy of an engine of this class instead of the relatively inefficient high pressure engine that is usually installed arranged for completion later by the addition of a low pressure side. Even should the high pressure side be run condensing, its performance would be bettered by the tandem compound condensing machine at least thirty per cent.

We furnished the Barker Cotton Mill Company, at Mobile, Alabama, with an engine of this type that has given the most thoroughly satisfactory results. The present installation consists of one side of the engine; the other side will be added when the mill is doubled up.

Corliss Engines, Continued.



(The above cut illustrates a Westinghouse Horizontal Cross Compound Corliss Engine, of the direct connected type—the Generator mounted on the engine shaft.)

Economy.

The consumption of steam in a given engine will vary with the conditions under which it is operated. In general, it is less expensive to overload an engine than underload it. By "overload" and "underload" is meant any departure from the conditions which secure best economy. As the result of a large number of experiments, which include some of the most exhaustive tests ever made, we feel warranted in drawing the following conclusions:

The economy of Single Cylinder Non-Condensing Engines may be stated as 24 to 27 pounds of steam per horse-power per hour when operated under the conditions expressed in our tables.

The same Engines Condensing, 19 to 22 pounds per horse-power per hour.

Compound Non-Condensing, 19 to 22 pounds per horse-power per hour.

Compound Condensing Engines, 11½ to 16 pounds per horse-power per hour.

Triple Expansion Engines, 11 to 13½ pounds per horse-power per hour.

Quadruple Expansion Engines are advisable only where very high steam pressures are employed, and where, for

Corliss Engines, Continued.

mechanical reasons, a four-cylinder machine is desirable. For all ordinary pressures the economy is about the same as Triple Expansion Engines.

And finally, the greatest economy is only obtained under the most favorable conditions.

Favorable Conditions for Economy.—It is obviously difficult to say in advance what will constitute favorable conditions under any and all circumstances. At the same time, the following points may be stated as among the most important:

(1). High steam pressures working through properly designed and properly proportioned engines.

(2). The piping leading from the main steam header in the boiler room to the throttle valve at the engine, must be as short and as straight as possible. Any elbows that are required should be of the long bend type; or, better still, bent steel elbows should be used with flanges peaned on.

(3). Dry steam is absolutely necessary for the best economy. An additional economy of seven to ten per cent. can be obtained by the use of superheated steam.

(4). As already stated above, the engine should be properly proportioned to the load, considering the local conditions that exist. The best results can not be expected from either a considerably overloaded or a considerably underloaded engine.

(5). To obtain a good vacuum on the condenser, the injection water must either be fairly cold in moderate quantity, or very ample if the temperature is liable to greatly exceed seventy degrees Fahrenheit the year round.

Also the condenser should be located as near as possible to the low pressure cylinder of the engine. The shorter the exhaust pipe leading from it to the condenser, the better the vacuum is likely to be.

Details of Engine Construction Affecting Economy:

(a). The ratio between the cylinders should be very carefully determined to suit local conditions. In general, for compound non-condensing engines, three and a half to one is recommended.

For compound condensing engines,—

For pressures under 140 pounds, four to one.

From 140 to 180 pounds, four and a half to one.

From 180 to 200 pounds, five to one.

These ratios should be strictly maintained. Taking steam from the receiver for heating or dye house purposes is a false idea of economy and a pernicious habit that can not be too strongly condemned. Low pressure steam for such purposes

Corliss Engines, Continued.

should properly be obtained through the medium of a reducing valve and taken directly from the main steam header. Of course, the objection to drawing steam from the receiver for these purposes is apparent, viz., the fact that the demand is an intermittent one. If the steam to be taken from the receiver were to be the same in amount the year round, the low pressure cylinder could be so proportioned as to take that loss into consideration.

In the same way, turning steam into the low pressure cylinder from the condenser, for instance, would be considered good practice, for it is a steady and continuous element that is introduced, and can therefore be considered and allowed for in determining the cylinder ratios.

(b). The valves must be properly set, and their positions carefully maintained.

Independent and separate eccentrics for actuating the steam and exhaust valves are absolutely necessary for the low pressure cylinder. Single eccentrics are practically as good, however, on the high presssure cylinder where the load is uniform.

Double ported valves should be used in all cases where the piston speed of the engine exceeds 750 feet per minute, and even where it exceeds 700 feet per minute is good practice. The object of the use of double ported valves is to give a larger opening for the quicker admission and exhaust of steam.

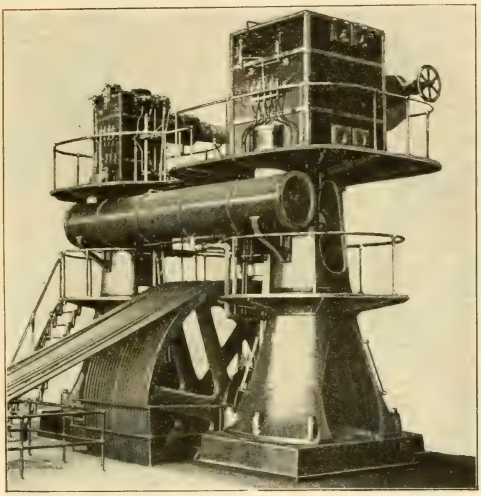
In general, the clearance in standard engines runs from 5% to 7%. In engines for electrical work, where the speeds are generally above the ordinary, the clearance is considerably more than in the slow speed machines, where the ports and steam passages are considerably smaller in area. Again, the actual clearance between piston and head can be less in slow speed machines, as water in that case is not encountered so often, and when it does occur it is not so dangerous.

The amount of clearance in engines is largely a commercial proposition, and can be made less if it is considered really desirable.

A considerable saving can be effected in the clearance by placing valves in the heads instead of in the corners of cylinders, which is the case in standard engines; this saving in clearance is about 33 1-3% for medium and small sized cylinders, and as much as 50% with the larger sizes. This means from 5% to 8% better economy in the performance of a compound engine.

(c). Receiver capacity should be from one and one-half to two times that of the high pressure cylinder.

Corliss Engines, Continued.



(Vertical Cross Compound, with Wheel for Rope Drive.)

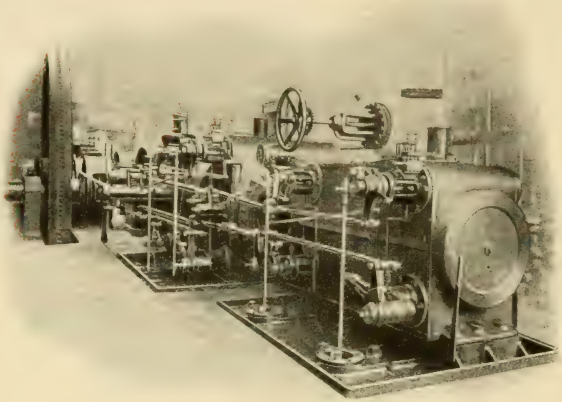
As to re-heating receivers, many tests have been made that go to show that the advantage claimed for it is exceedingly slight. The losses very nearly if not entirely outweigh the corresponding gains.

(d). Where a high pressure condenser is used, and not a compound machine, as has been already stated, the exhaust from it may be turned into the receiver between the engine cylinders. The effect of this, however, should be carefully considered in proportioning the engine cylinders.

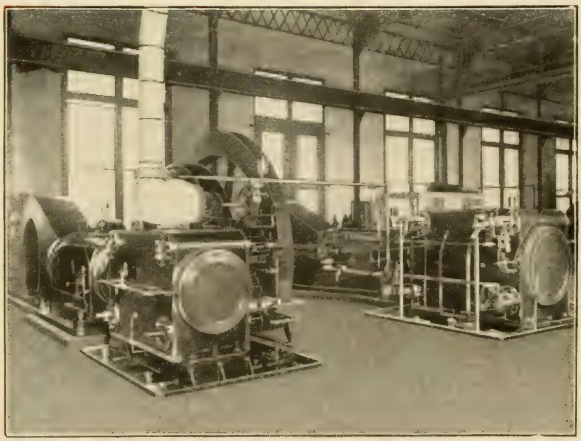
(e). Steam jacketing cylinders is recommended for engines of very slow piston speed, but it is seldom applied to anything except triple and quadruple expansion machines. Some engineers recommend steam jacketing the cylinders of compound engines, but it is exceedingly doubtful if that is at all profitable. The losses are likely to exceed the gains. Very few, if indeed any, compound engines, therefore, are now made with steam jacketed cylinders. Superheating the steam is a much more efficient way of making up cylinder losses.

Finally, it will be noted that all of the above considerations affect steam consumption and engine performance only. Coal consumption, or the performance of the boilers and the usual accessories, is considered elsewhere.

Corliss Engines, Continued.

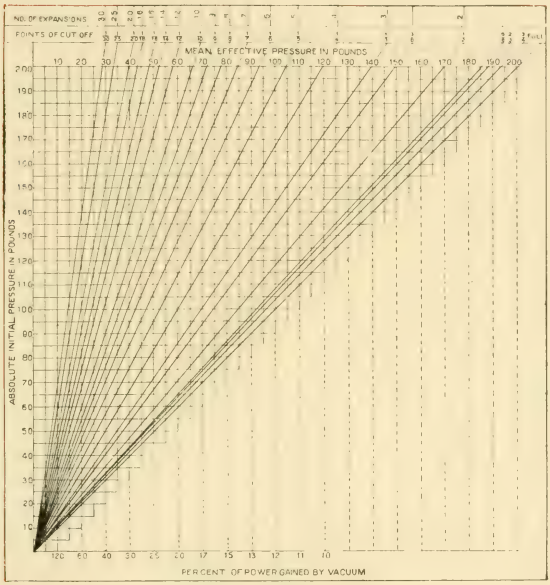


(Westinghouse Horizontal Tandem Compound Corliss Engine, direct connected to power generator.)



(Westinghouse Horizontal Cross Compound Corliss Engine, direct connected to power generator.)

Corliss Engines, Continued.


NO. OF EXPANSIONS
POINTS OF CUT OFF
MEAN EFFECTIVE PRESSURE IN POUNDS
ABSOLUTE INITIAL PRESSURE IN POUNDS
PERCENT OF POWER GAINED BY VACUUM

(Chart of M. E. Ps.)

Mean Effective Pressures.

All horse power tables are based upon calculated mean effective pressures, with such modifications as the experience of the particular builder suggests.

Owing to the diversity of opinion on this subject, it would seem inadvisable to publish a table of mean effective pressures; yet, at the same time, it has seemed necessary to do so to meet the wants of those who have occasion to consider special cases not covered in the tables. In offering this chart of mean effective pressures, we do so without comment.

The tables of horse powers, however, included in this chapter, represent the best practice of to-day, and have been adopted by most of the engine builders of the country; they can therefore safely be accepted as conclusive.

Corliss Engines, Continued.

Table of Horse Powers, Simple Non-Condensing Engines.

Cylinder.			Indicated Horse Power at the Following Gauge Pressures.													
			80 lbs.		90 lbs.		100 lbs.		110 lbs.		120 lbs.		130 lbs.		140 lbs.	
Diameter, in Inches.	Stroke, in Inches.	Revolutions per Minute.	Cut-off.		Cut-off.		Cut-off.		Cut-off.		Cut-off.		Cut-off.		Cut-off.	
			1/5	1/4	1/5	1/4	1/5	1/4	1/5	1/3	1/5	1/4	1/6	1/4	1/5	1/4
8	24	100	21	26	24	29	27	33	30	36	33	39	36	42	39	45
10	30	90	37	45	42	51	48	58	53	64	58	69	64	75	68	81
12	30	90	54	65	62	74	69	83	77	89	84	100	92	108	101	116
12	36	85	61	73	70	84	78	94	87	101	95	112	104	123	114	131
14	36	85	83	100	95	114	107	128	119	138	130	153	142	168	126	179
14	42	82	93	112	107	128	120	144	134	155	145	172	160	188	175	201
16	36	82	105	126	120	144	135	162	150	174	163	193	179	210	197	226
16	42	78	116	139	133	159	150	179	167	193	180	214	198	233	218	250
18	36	80	129	155	148	177	166	199	186	215	201	238	221	260	243	279
18	42	78	147	176	168	202	189	227	211	245	227	271	251	295	276	317
18	48	75	162	195	185	222	208	249	232	269	251	298	276	325	303	348
20	42	75	175	210	200	240	225	270	250	290	272	322	298	350	328	376
20	48	72	192	230	219	263	246	296	275	318	300	352	327	385	360	412
20	60	65	216	260	248	297	279	334	310	359	336	400	370	436	406	466
22	42	75	211	254	242	290	271	326	303	351	328	390	360	426	396	455
22	48	72	232	278	265	318	298	358	333	385	361	428	395	466	436	500
22	60	65	262	314	299	359	336	404	376	435	407	482	447	528	490	563
24	48	70	268	322	307	368	345	414	385	446	417	494	458	540	503	577
24	60	65	311	374	356	427	401	481	448	518	484	575	530	625	584	671
26	48	70	315	378	360	432	405	486	452	523	490	580	538	635	590	677
26	60	65	366	439	418	502	470	564	525	608	570	675	625	735	682	784
28	48	68	355	426	406	487	457	548	510	590	550	655	605	715	666	765
28	60	65	424	509	485	582	545	654	609	705	660	790	725	855	794	912
30	48	68	407	489	466	559	524	629	585	678	635	750	695	820	764	877
30	60	62	464	557	531	637	597	717	667	772	720	858	790	935	872	1000

Table of Horse Powers, Simple Non-Condensing Engines, Concluded.

Cylinder.		Revolutions per Minute.	Indicated Horse Power at the following Gauge Pressures.													
			80 lbs.		90 lbs.		100 lbs.		110 lbs.		120 lbs.		130 lbs.		140 lbs.	
Diameter, in inches.	Stroke, in inches.		Cut-off.		Cut-off.		Cut-off.		Cut-off.		Cut-off.		Cut-off.		Cut-off.	
			1/5	1/4	1/5	1/4	1/5	1/4	1/5	3/4	1/5	1/4	1/5	1/4	1/5	1/4
30	72	55	494	593	565	678	635	762	710	822	770	910	845	995	925	1062
32	48	65	443	532	507	608	570	684	637	737	690	818	760	895	832	955
32	60	62	529	634	604	725	680	816	759	878	820	975	900	1065	990	1137
32	72	55	563	675	643	772	723	868	808	935	875	1035	960	1135	1055	1211
34	48	65	500	600	572	686	644	772	719	833	780	925	855	1010	938	1077
34	60	62	597	716	682	818	767	920	857	992	910	1100	1020	1200	1118	1284
34	72	55	635	762	726	871	817	980	913	1056	990	1170	1085	1280	1191	1367
36	48	62	535	642	611	749	688	825	769	890	830	990	915	1080	1003	1152
36	60	62	669	803	765	918	860	1032	961	1112	1040	1235	1140	1350	1254	1440
36	72	55	711	853	814	977	916	1099	1023	1184	1110	1310	1215	1435	1335	1532
38	60	60	722	866	824	1007	928	1113	1037	1200	1120	1330	1230	1450	1340	1539
40	48	70	746	895	852	1044	959	1150	1072	1240	1160	1375	1275	1500	1399	1605
40	60	62	826	991	944	1133	1062	1274	1187	1373	1285	1520	1410	1665	1548	1777
40	72	55	879	1055	1005	1206	1130	1355	1264	1462	1370	1620	1500	1770	1648	1892
40	84	50	932	1119	1066	1305	1199	1439	1340	1551	1450	1720	1590	1880	1748	2007
42	48	70	822	987	940	1151	1057	1269	1182	1367	1280	1515	1400	1655	1541	1770
42	60	62	910	1092	1041	1249	1171	1405	1308	1514	1415	1675	1550	1830	1707	1960
42	72	55	969	1163	1108	1330	1246	1496	1393	1612	1505	1785	1650	1950	1817	2086
44	48	70	900	1083	1031	1234	1039	1393	1298	1501	1400	1666	1540	1815	1692	1943
44	60	62	998	1197	1142	1370	1285	1542	1436	1663	1550	1830	1700	2000	1873	2150
44	72	55	1063	1275	1216	1459	1368	1642	1529	1769	1650	1960	1810	2140	1995	2290
46	60	62	1092	1310	1249	1499	1405	1686	1570	1817	1700	2015	1865	2200	2048	2351
46	72	55	1163	1396	1329	1595	1495	1794	1671	1934	1805	2140	1980	2340	2180	2502
48	60	62	1190	1428	1360	1632	1530	1835	1710	1978	1850	2190	2030	2400	2230	2560
48	72	55	1266	1520	1447	1737	1628	1954	1820	2106	1970	2330	2160	2550	2375	2726

Corliss Engines, Continued.

Table of Horse Powers, Compound Condensing Engines.

(Cylinder Ratio 4 to 1.)

Cylinders, in Inches.			Revolutions per Minute.	Indicated Horse Power at ¼ Cut-off for the Following Gauge Pressures.						
High Pressure.	Low Pressure.	Stroke.		80 lbs.	90 lbs.	100 lbs.	110 lbs.	120 lbs.	130 lbs.	140 lbs.
12	24	30	120	150	156	168	174	192	204	222
12	24	36	100	150	156	168	174	192	204	222
14	28	30	120	204	216	228	234	258	282	306
14	28	36	100	204	216	228	234	258	282	306
14	28	42	90	214	227	240	246	271	296	321
16	32	30	120	264	276	294	306	336	366	396
16	32	36	100	264	276	294	306	336	366	396
16	32	42	90	277	290	309	321	353	384	416
18	36	36	100	336	354	372	390	426	462	498
18	36	42	90	353	372	391	410	448	485	523
18	36	48	80	358	378	397	416	454	493	531
20	40	36	100	414	432	456	480	528	570	618
20	40	42	90	435	454	479	504	555	598	649
20	40	48	80	442	461	486	512	563	608	660
22	44	42	90	523	555	580	611	668	725	781
22	44	48	80	531	563	589	621	679	736	794
24	48	42	90	624	655	693	725	794	864	933
24	48	48	80	634	666	704	736	806	877	948
26	52	48	80	742	781	826	864	917	1030	1114
26	52	60	75	876	915	968	1012	1109	1207	1304
28	56	48	80	865	909	954	1004	1100	1196	1292
28	56	60	75	1012	1064	1116	1176	1289	1402	1514
30	60	48	80	986	1043	1094	1152	1260	1368	1477
30	60	60	75	1154	1222	1282	1348	1477	1604	1732
32	64	60	75	1312	1387	1462	1536	1679	1828	1972
36	72	60	75	1656	1762	1852	1948	2129	2318	2497

Note.—The table above and on the following page gives the horse powers of compound engines at 1-4 cut-off and at the speed given.

To find the horse power at different speeds, and at both 1-4 and 4-10 cut-off, see general table of "Horse Powers for Compound Condensing Engines at 100 Feet Piston Speed per Minute," on page 624.

Corliss Engines, Continued.

Table of Horse Powers, Compound Condensing Engines, Concluded.

(Cylinder Ratio 4 to 1, also 4½ and 5 to 1.)

Cylinders in Inches.			Revolutions per Minute.	Indicated Horse Power at ¼ Cut-off for the Following Gauge Pressures.						
High Pressure.	Low Pressure.	Stroke.		140 lbs.	150 lbs.	160 lbs.	170 lbs.	180 lbs.	190 lbs.	200 lbs.
12	24	30	120	222	240	248	258	266	274	282
12	24	36	100	222	240	248	258	266	274	282
14	28	30	120	306	324	337	350	362	373	384
14	28	36	100	306	324	337	350	362	373	384
14	28	42	90	321	340	354	368	380	392	403
16	32	30	120	396	426	440	458	473	487	502
16	32	36	100	396	426	440	458	473	487	502
16	32	42	90	416	447	462	481	496	511	527
18	36	36	100	498	540	557	579	598	617	635
18	36	42	90	523	567	585	608	628	647	666
18	36	48	80	531	576	595	618	638	658	677
20	40	36	100	618	660	688	715	738	761	784
20	40	42	90	649	693	722	751	775	798	823
20	40	48	80	660	704	734	763	787	812	836
22	44	42	90	781	845	875	909	938	968	996
22	44	48	80	794	858	887	923	952	981	1012
24	48	42	90	933	1000	1040	1080	1116	1150	1185
24	48	48	80	948	1019	1056	1098	1133	1170	1203
26	52	48	80	1114	1196	1239	1278	1329	1370	1410
26	52	60	75	1304	1402	1452	1510	1558	1607	1655
28	56	48	80	1292	1334	1438	1497	1545	1591	1640
28	56	60	75	1514	1626	1685	1752	1810	1865	1920
30	60	48	80	1477	1586	1650	1718	1770	1825	1880
30	60	60	75	1732	1858	1932	2005	2075	2138	2200
32	64	60	75	1972	2121	2200	2285	2360	2430	2505
36	72	60	75	2497	2684	2780	2890	2985	3080	3170
Ratio 4½ to 1				.986	.964	.963	.961	.960	.953	.946
Ratio 5 to 1				.960	.939	.937	.933	.926	.920	.910

Note.—In order to find the horse power of an engine for 4½ or 5 to 1 ratios, multiply the horse power given in the table above by the constant opposite the ratio selected at the foot of the table.

This is based upon the assumption that the low pressure cylinder remains the same as given above, the high pressure cylinder being made smaller.

Table of Horse Powers per 100 Feet Piston Speed,

Compound Condensing Engines, Cylinder Ratios 4 to 1.

Diameter L. P. Cylinder.	Gauge Pressure in Pounds.															
	80		90		100		110		120		130		140		150	
	M. E. P.		M. E. P.		M. E. P.		M. E. P.		M. E. P.		M. E. P.		M. E. P.		M. E. P.	
	18	26	19	28	20	30	21	32	23	34	25	37	27	39	29	42
16	10	16	12	17	12	18	13	20	14	21	15	23	16	24	18	26
20	17	25	18	27	19	29	20	30	22	32	24	35	26	37	28	40
24	25	36	26	30	28	41	29	44	32	47	34	51	37	54	40	58
28	34	49	36	53	38	56	39	60	43	64	47	60	51	73	54	79
32	44	63	46	68	49	73	51	78	56	83	61	90	66	95	71	102
36	56	80	59	86	62	93	65	99	71	105	77	114	83	120	90	130
40	69	99	72	107	76	114	80	122	88	130	95	141	103	149	110	160
44	83	120	88	129	92	138	97	147	106	157	115	170	124	180	134	193
48	99	113	104	154	110	165	115	176	126	187	137	203	148	214	159	230
52	116	167	122	180	129	193	135	206	148	219	161	238	174	251	187	270
56	135	195	142	209	149	224	157	239	172	254	187	277	202	292	217	314
60	154	223	163	240	171	257	180	274	197	291	214	317	231	334	248	360
64	175	253	185	273	195	292	205	312	224	331	244	360	263	380	283	410
68	198	286	209	308	220	330	231	352	253	374	275	407	297	429	319	462
72	221	321	235	346	247	370	260	395	284	420	309	457	333	482	358	518
76	247	357	261	385	275	412	289	440	316	467	343	508	371	536	398	577
80	274	396	289	426	305	457	320	487	350	518	380	563	411	594	442	640
84	302	457	319	470	336	504	353	537	386	571	420	621	453	655	487	705
88	332	480	350	516	360	553	387	590	424	627	461	682	498	719	534	774
92	365	524	385	564	405	604	426	644	463	684	503	745	544	785	584	846
96	395	570	416	614	438	658	460	701	504	745	548	810	592	854	636	920
100	428	618	452	666	475	714	500	761	547	808	594	880	642	928	690	998

NOTE—The double columns above are for $\frac{1}{4}$ and $\frac{4}{10}$ cut-off respectively.

Corliss Engines, Continued.

Table of Sizes and Details, Simple Non-Condensing Engines.

(Belted Girder Type.)

Cylinder.		Wheel.		Length of Shaft.	Approx. Dimens'ns, Feet and Inches.					Diam. of Pipes.	
					Width Overall.						
Diameter, in Inches.	Stroke, in Inches.	Diameter, in Feet.	Face, in Inches.	Belting Forward, in Feet and Inches.	Belting Backward in Feet and Inches.	Centre of Shaft to Back of Cylinder Head.	Center of Shaft to top of Foundation.	Length of Engine, Overall.	Belting Forward. W 1	Belting Backward. W 2	Steam Pipe, in Inches.	Exhaust Pipe, in Inches.
8	24	7	11	5– 0	6–10	11– 3	25	14– 9	6– 0	7–10	2½	3
10	30	8	13	5– 3	7– 2	13– 6	25	17– 6	6– 5	8– 4	3	4
12	30	9	15	6– 0	7– 6	14– 0	25	18– 6	7– 4	9– 0	4	5
12	36	10	17	6– 2	7–10	16– 3	25	21– 3	7– 6	9– 2	4	5
14	36	10	19	6– 9	8– 3	16– 3	25	21– 3	8– 2	9– 8	4	6
14	42	12	19	6– 9	8– 3	18– 3	25	24– 3	8– 2	9– 8	4	6
16	36	12	21	7– 1	8– 8	16– 6	27	22– 6	8– 7	10– 2	5	6
16	42	12	23	7– 3	8–10	18– 6	27	24– 6	8– 9	10– 4	5	6
18	36	12	25	7–10	9– 2	16– 9	30	22– 9	9– 5	10–11	5	7
18	42	14	23	7– 8	9– 0	18– 9	30	25– 9	9– 5	10– 9	5	7
18	48	15	25	7–10	9– 2	21– 0	30	28– 6	9– 7	10–11	5	7
20	42	15	25	8– 0	9– 6	18–10	30	26– 4	9–10	11– 4	6	8
20	48	16	27	8– 2	9– 8	21– 1	30	29– 1	10– 0	11– 6	6	8
20	60	16	31	8– 6	10– 0	25– 7	30	33– 7	10– 4	11–10	6	8
22	42	16	29	8– 6	10– 0	19– 1	32	27– 1	10– 6	12– 0	6	8
22	48	16	33	8–10	10– 4	21– 4	32	29– 4	10–10	12– 4	6	8
22	60	18	35	9– 0	10– 6	25–10	32	31–10	11– 0	12– 6	6	8
24	48	18	35	9– 4	10– 9	21– 6	32	30– 6	11– 5	12–10	7	9
24	60	20	40	9– 9	11– 2	26– 1	32	36– 1	11–10	13– 3	7	9
26	48	18	42	9–11	11– 5	21– 9	34	30– 9	12– 1	13– 7	7	10
26	60	20	48	10– 5	11–11	26– 3	34	36– 3	12– 7	14– 1	7	10
28	48	20	44	10–10	11–11	22– 0	34	32– 0	13– 2	14– 3	8	10
28	60	22	50	11– 4	12– 5	26– 4	34	37– 4	13– 8	14– 9	8	10
30	60	24	52	11– 7	13– 0	28– 6	36	40– 0	14– 1	15– 6	9	12
30	72	24	60	12– 3	13– 8	32– 6	36	34– 6	14– 9	16– 2	9	12

Corliss Engines, Continued.

Table of Sizes and Details, Simple Non-Condensing Engines.

(Belted Heavy Duty Type.)

Cylinder.		Wheel.		Length of Shaft.		Approx. Dimensions, Feet and Inches.					Diam. of Pipes.	
								Width Overall.				
Diameter, in Inches.	Stroke, in Inches.	Diameter, in Feet.	Face, in Inches.	Belting Forward, in Feet and Inches.	Belting, Backward, in Feet and Inches.	Centre of Shaft to Back of Cylinder Head.	Centre of Shaft to Top of Foundation.	Length of Engine Overall.	Belting Forward. W 1	Belting Backward. W 2	Steam Pipe, in Inches.	Exhaust Pipe, in Inches.
12	30	9	15	6 5	7–11	11– 0	25	18– 6	8– 2	9– 8	4	5
12	36	10	17	6– 7	8– 1	10– 3	25	21– 3	8– 4	9–10	4	5
14	36	10	19	6– 9	8– 6	10– 4	25	21– 4	8– 6	10– 3	4	6
14	42	12	19	6– 9	8– 6	10– 7	25	24– 7	8– 6	10– 3	4	6
16	36	12	21	7– 1	8–11	10– 8	30	24– 8	9– 2	11– 0	5	6
16	42	12	23	7– 3	9– 1	10–11	30	24–11	9– 4	11– 2	5	6
18	36	12	25	7– 8	9– 5	10–10	30	22–10	9– 9	11– 6	5	7
18	42	14	23	7– 6	9– 3	10– 1	30	26– 1	9– 7	11– 4	5	7
18	48	15	25	7– 8	9– 5	11– 4	30	28–10	9– 9	11– 6	5	7
20	42	15	25	7–11	10– 0	11– 5	32	26–11	10– 5	12– 6	6	8
20	48	16	27	8– 1	10– 2	11– 8	32	29– 8	10– 7	12– 8	6	8
20	60	16	31	8– 5	10– 6	12– 2	32	34– 2	10–11	13– 0	6	8
22	42	16	29	8– 7	10– 7	11– 6	32	27– 6	11– 1	13– 1	6	8
22	48	16	33	8–11	10–11	11– 9	32	29– 9	11– 5	13– 5	6	8
22	60	18	35	9– 1	11– 1	12– 3	32	35– 3	11– 7	13– 7	6	8
24	48	18	35	9– 4	11– 4	12– 2	34	31– 2	12– 3	14– 3	7	9
24	60	20	40	9– 9	11– 9	12– 8	34	36– 8	12– 8	14– 8	7	9
26	48	18	42	9–11	11–11	12– 2	34	31– 2	12–10	14–10	7	10
26	60	20	48	10– 5	12– 5	12– 8	34	36– 8	13– 4	15– 4	7	10
28	48	20	44	10–11	12– 8	12– 7	36	32– 7	14– 1	15– 7	8	10
28	60	22	50	11– 5	13– 2	12– 8	36	28– 1	14– 7	16– 1	8	10
30	48	22	46	11– 2	13– 1	12–10	36	33–10	14– 4	16– 0	9	12
30	60	24	52	11– 8	13– 7	13– 2	36	39– 4	14–10	16– 6	9	12
30	72	24	60	12– 6	14– 3	13– 0	38	45– 0	15– 8	17– 3	9	12

Corliss Engines, Continued.

Table of Sizes and Details, Simple Non-Condensing Engines.

(Belted Heavy Duty Type, Concluded.)

Cylinder.		Wheel.	Length of Shaft.		Approx. Dimens'ns, Feet and Inches				Diam. of Pipe.	
Diameter, in Inches.	Stroke, in Inches.	Diameter, in Feet.	Belting Forward, in Feet and Inches.	Belting Backward, in Feet and Inches.	Centre of Shaft to Back of Cylinder Head.	Centre of Shaft to Top of Foundation.	Length of Engine Overall.	Width Overall. Belting Forward. W 1	Width Overall. Belting Backward. W 2	Steam Pipe, in Inches.	Exhaust Pipe, in Inches.
32	48	24	11–11	13–7	25–2	38	35–2	15–6	17–2	10	12
32	60	24	12–11	14–7	27–8	38	39–8	16–6	18–2	10	12
32	72	24	13–5	15–1	32–2	38	44–2	17–0	18–8	10	12
34	48	24	12–1	13–11	23–3	38	35–3	15–8	17–6	10	12
34	60	24	13–1	14–11	27–9	38	39–9	16–8	18–6	10	12
34	72	24	14–1	15–11	32–3	38	44–3	18–8	19–6	10	12
36	48	24	13–0	15–1	23–6	40	35–6	16 11	19–0	10	12
36	60	24	14–2	16–3	28–0	40	40–0	18–1	20–2	10	12
36	72	26	14–4	16–5	32–6	40	45–6	18–3	20–4	10	12
38	60	24			28–1	40	41–1			12	14
40	60	24			28–5	42	41–5			12	14
40	72	26			28–6	42	40–6			12	14
40	84	30			33–0	42	46–0			12	14
42	48	26			23–6	42	52–6				
42	60	26			28–6	42	38–6				
42	72	26			33–7	42	41–7				
44	60	26			28–10	46	46–1				
44	72	26			33–1	46	38–10				
46	60	30			28–11	46	41–11				
46	72	30			33–5	46	46–5				
48	60	30			28–11	46	43–11				
48	72	30			33–5	46	48–5				
					29–6	48	44–6				
					34–0	48	49–0				

Corliss Engines, Continued.

Notes on Diagrams and Dimension Tables.

On the following pages will be found diagrams and tables giving dimensions of different types of engines.

Single cylinder engines are built both with heavy duty and girder frames. We do not, however, advocate the use of engines with girder frames.

Compound engines should be built only with heavy duty frames, as this is the type of engine that has gradually become the standard for cotton mill use—not to mention the fact that the heavy duty frame is the only one at all adapted to work under the modern conditions of high pressure required for compound engines.

Nothing whatever has been put in on the subject of triple and quadruple expansion engines, as there are very few, if indeed any, of either type in textile mills; and certainly the present practice is not in favor of using them.

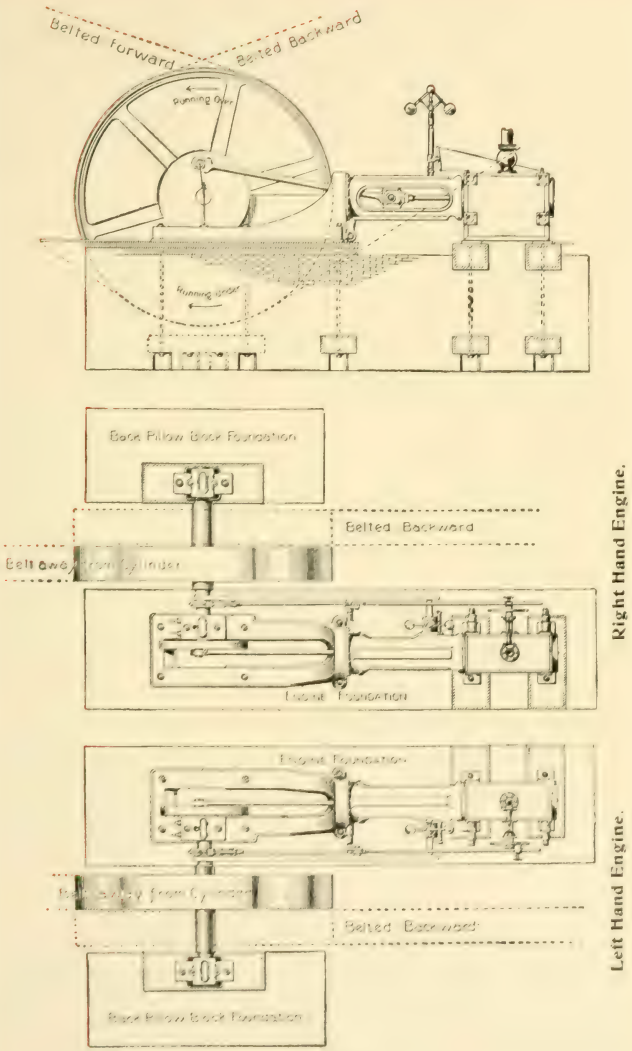
Nor is anything given for single cylinder vertical engines, nor for steeple compound (tandem) vertical engines; the use of vertical engines in the cotton mill trade is practically restricted to vertical cross compound, and that type therefore only has been considered.

The **allowances** that will have to be made for **different sized wheels** are self-evident. It is not out of place to call attention, however, to the cuts on page 363 for figuring the width of the face of rope wheels; the number of ropes to transmit the horse power is of course determined by taking from the tables on pages 620 to 624 inclusive, the horse power of the engine selected, and allowing the proper number of ropes required to transmit that horse power, derived from Table 2 on page 364.

It is out of the question, however, to give any rule for making **allowances** in the above tables for **engines with direct connected generators**: the width of the generator itself depends upon a number of electrical considerations, such as the size of the generator in kilowatts; whether direct current or alternating current machines; if alternating current, the number of cycles, revolutions per minute, etc.

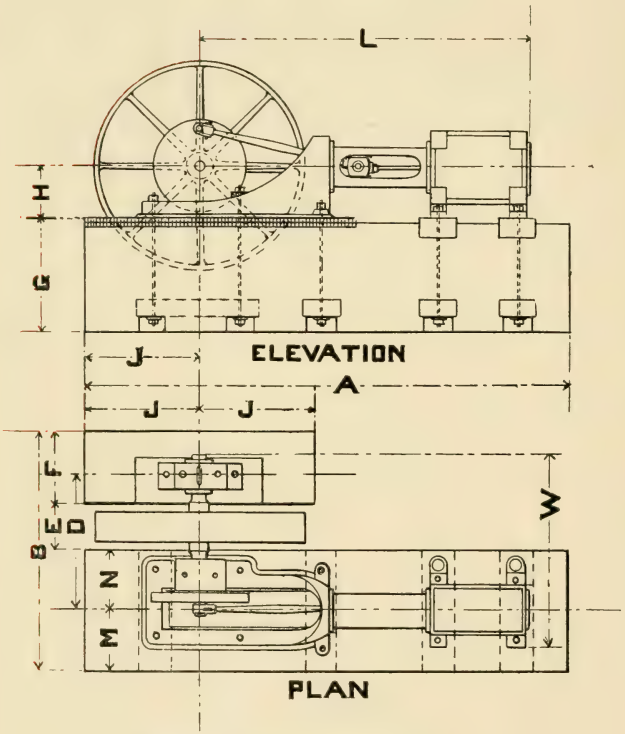
Still, the tables given on the following pages will answer for estimating purposes. Blue prints should always be obtained from the builder for piping up or construction work.

The lettered **dimensions** in the table for the different types of **compound engines are given for cylinder ratios of approximately 4 1-2 to 1.** The proper **allowances** for two or three inches more or less of cylinder diameter can easily be made to suit engines of **other cylinder ratios**



Explanatory Diagrams.

Corliss Engines, Continued.



Dimension and Foundation Diagrams.

Heavy Duty Type, Simple Non-Condensing Engines.

(Belted Type.)

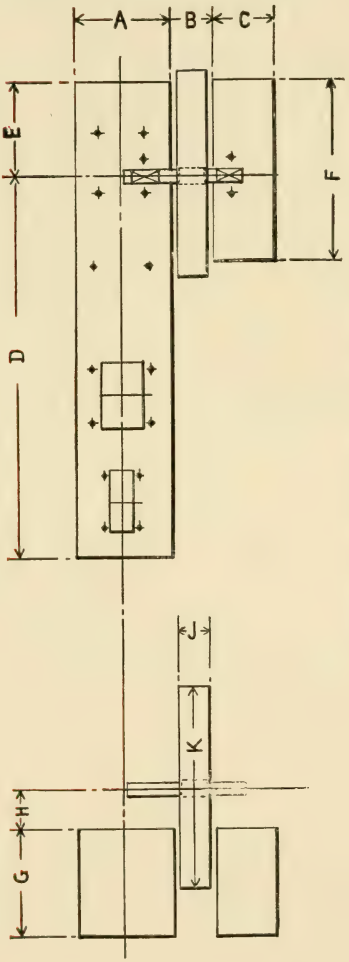
Table of Lettered Dimensions of Standard Sizes.

Belted Heavy Duty Type, Simple Non-Condensing Engines.

Cylinder.		Wheel.		Dimensions, in Feet and Inches.										
Diam., in Inches.	Stroke, in Inches.	Diam., in Feet.	Face, in inches.	A	B	D	E	F	G	K	L	M	N	H (In in.)
12	30	9	15	21-0	11-9	6-0	1-9	4-0	6-0	5-0	14- 0	2-9	3-3	25½
12	36	10	17	23-0	11-11	6-2	1-11	4-0	6-0	5-0	16- 3	2-9	3-3	25½
14	36	10	19	23-0	12-1	6-4	2- 1	4-0	6-0	5-0	16- 4	2-9	3-3	25½
14	42	12	19	25-0	12-1	6-4	2- 1	4-0	6-0	5-0	18- 7	2-9	3-3	25½
16	36	12	21	25-0	12-3	6-6	2- 3	4-0	6-6	6-6	16- 8	2-9	3-3	30½
16	42	12	23	27-0	12-5	6-8	2- 5	4-0	6-6	6-6	18-11	2-9	3-3	30½
18	36	12	25	25-0	14-1	7-1	2- 7	5-0	7-0	6-6	16-10	3-0	3-6	30½
18	42	14	23	27-6	13-11	6-11	2- 5	5-0	7-0	6-6	19- 1	3-0	3-6	30½
18	48	15	25	29-6	14-1	7-1	2- 7	5-0	7-0	6-6	21- 4	3-0	3-6	30½
20	42	15	25	28-0	14-1	7-4	2- 7	5-0	7-0	6-6	19- 5	3-0	3-6	32¾
20	48	16	27	30-0	14-3	7-6	2- 9	5-0	7-6	6-6	21- 8	3-0	3-6	32¾
20	60	16	31	34-6	14-7	7-10	3- 1	5-0	7-6	6-6	26- 2	3-0	3-6	32¾
22	42	16	29	28-6	14-11	7-11	2-11	5-0	8-0	7-0	19- 6	3-3	3-9	32¾
22	48	16	33	30-6	15-3	8-3	3- 3	5-0	8-0	7-0	21- 9	3-3	3-9	32¾
22	60	18	35	35-0	15-5	8-5	3- 5	5-0	8-0	7-0	26- 3	3-3	3-9	32¾
24	48	18	35	32-6	15-11	8-8	3- 5	5-0	8-6	8-0	22- 2	3-6	4-0	34¾
24	60	20	40	37-0	16-4	9-1	3-10	5-0	8-6	8-0	26- 8	3-6	4-0	34¾
26	48	18	42	32-6	17-0	9-3	4- 0	5-0	9-0	8-0	22- 2	4-0	4-0	34¾
26	60	20	48	37-0	17-6	9-9	4- 6	5-0	9-0	8-0	26- 8	4-0	4-0	34¾
28	48	20	44	33-6	18-2	10-2	4- 2	5-0	9-6	8-0	22- 7	4-6	4-6	36¾
28	60	22	50	38-0	18-8	10-8	4- 8	5-0	9-6	8-0	27- 1	4-6	4-6	36¾
30	48	22	46	34-6	18-10	10-4	4- 4	5-6	10-0	9-0	22-10	4-6	4-6	36¾
30	60	24	52	39-0	19-4	10-10	4-10	5-6	10-0	9-0	27-4	4-6	4-6	36¾

Note.—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purpose of installation.

Corliss Engines, Continued.



Dimension and Foundation Diagrams.

Heavy Duty Tandem Compound Condensing Engines.

(Belted Type).

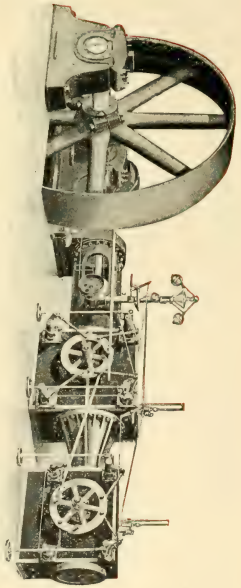
Table of Lettered Dimensions,

Heavy Duty Tandem Compound Condensing Engines.

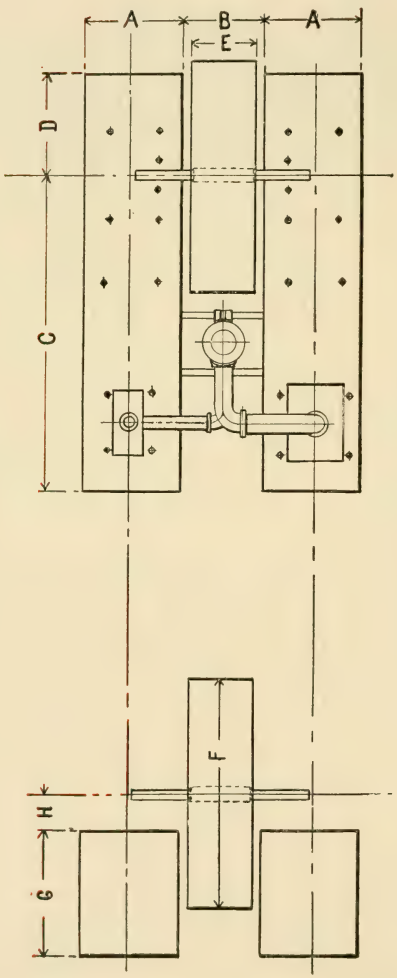
(Belted Type).

Cylinders, in Inches.			Approximate Dimensions of Standard Engines. (See Diagrams on Opposite Page.)									
High Pressure.	Low Pressure.	Stroke.	A In Feet and Inches.	B In Feet and Inches.	C In Feet and Inches.	D In Feet.	E In Feet.	F In Feet.	G In Feet and Inches.	H In Inches.	J In Inches	K In Feet.
12	26	36	6-3	2- 5	4-0	25	7	14	6-0	25½	23	14
14	30	42	6-6	2- 9	5-0	28	7	14	7-0	30½	27	16
16	34	42	7-0	3- 3	5-0	29	7	14	8-0	32¾	33	16
18	38	42	7-0	4- 0	5-0	30	7	14	8-0	34¾	42	18
18	38	48	7-0	3-10	5-0	33	8	16	8-6	34¾	40	18
20	44	48	7-6	5- 2	6-0	34	8	16	8-6	36¾	56	20
22	48	48	8-0	6- 0	6-0	34	8	16	8-6	36¾	66	20
24	52	48	8-6	7- 0	6-0	35	8	16	8-6	38¾	78	20
26	52	60	9-0	6- 6	6-0	42	9	18	9-0	38¾	72	22
26	56	48	9-6	8-10	6-0	35	9	18	9-6	40¾	100	22
26	56	60	9-6	8- 6	6-0	42	9	18	10-0	40¾	96	24
28	60	60	10-0	9- 6	6-6	43	10	20	11-0	42¾	108	24
30	64	60	11-0	10- 6	6-6	43	10	20	11-0	42¾	120	24

Note.—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purposes of installation.



Corliss Engines, Continued.



Dimension and Foundation Diagrams.

For Heavy Duty Cross Compound Condensing Engines.

(Belted Type).

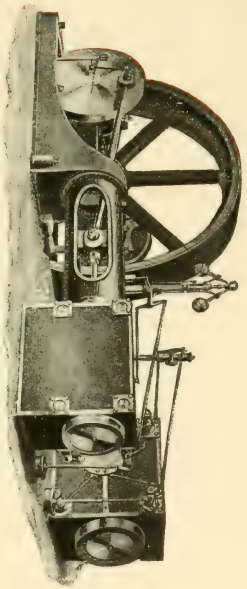
Table of Lettered Dimensions,

Heavy Duty Cross Compound Condensing Engines.

(Belted Type)

Cylinders, in Inches.			Approximate Dimensions of Standard Engines. (See Diagrams on Opposite Page.)							
High Pressure.	Low Pressure.	Stroke.	A	B	C	D	E	F	G	H
			In Feet and Inches.	In Feet and Inches	In Feet and Inches.	In Feet and Inches	In Inches.	In Feet.	In Feet and Inches.	In Inches.
12	26	36	6-0	2-5	18-0	5-0	23	14	6-0	25 1/2
14	30	42	6-0	2-9	20-6	6-0	27	16	6-6	28 1/2
16	34	42	6-0	3-3	20-6	6-0	33	16	6-6	30 1/2
18	38	42	6-6	4-0	21-0	6-6	42	18	7-0	30 1/2
18	38	48	6-6	3-10	23-0	6-6	40	18	7-0	30 1/2
20	44	48	7-0	5-2	24-0	7-0	56	20	7-6	32 3/4
22	48	48	7-3	6-0	24-0	7-0	66	20	8-0	32 3/4
24	52	48	7-6	7-0	24-6	8-0	78	20	8-0	34 3/4
26	52	60	8-0	6-6	29-0	8-0	72	22	9-6	34 3/4
26	56	48	8-6	8-10	24-6	8-0	100	22	9-6	34 3/4
26	56	60	8-6	8-6	29-0	8-0	96	24	9-6	34 3/4
28	60	60	9-6	9-6	30-0	9-0	108	24	10-0	36 3/4
30	64	60	9-6	10-6	30-0	9-0	120	24	10-0	36 3/4

Note.—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purposes of installation.

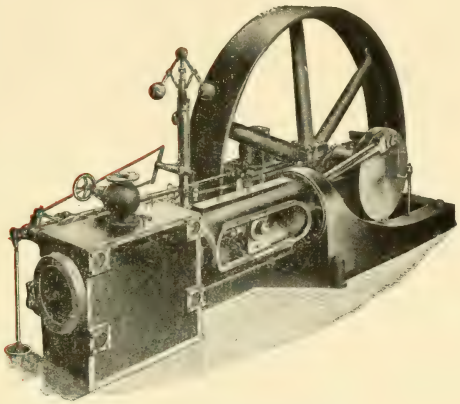


Corliss Engines, Continued.

Standard Specifications.

Certain standard types of engines are built for the convenience of customers to whom quick delivery is of vital importance; the parts of such standard engines can generally be assembled and shipped out very promptly. For the convenience of such customers, and others, the following standard specifications are given; feasible variations from them will be found under the head of "**Notes on Specifications,**" on page 655.

Corliss Engines, Continued.



Standard Specification.

For Belted Type, Heavy Duty Frame, Horizontal Corliss Engine.

Type.—The engine will be a horizontal————————condensing machine, with cylinder ————————inches diameter, ————————inches stroke. Engine to run ————————revolutions per minute, with ————————pounds steam pressure. Engines to be ————————hand.

Belt (Away from cylinder.) See page 629.
(Back by cylinder)

Cylinder.—This will be made of hard, close grained iron; will be covered with non-conducting material, and lagged with sheet steel, held in place by polished corner irons. The cylinder will be made with exhaust chamber separated by an air space from the cylinder barrel, reducing the internal condensation. The back cylinder head will have a false cover.

Valve Gear.—Cylinder will be furnished with Corliss automatic valve gear and standard type of governor. The valves to be double ported. Wrist plate will be provided with patent disconnecting device, so that the valve gear can be worked by hand.

The liberating catches of valve gear are made of hardened steel, of such form that eight wearing surfaces are available

Corliss Engine, Continued.

by change of position, each new position restoring valve adjustment to original setting.

Frame.—The frame will be the heavy duty pattern with broad bearing surface to rest on foundation, with plate cast in bottom, to form a receptacle for oil thrown off by the crank pin, journal or slides. At the bottom of frame there will be a suitable hole drilled and tapped at the lowest point for a pipe to drain off the oil collected.

Main journal will be————inches diameter and———— inches long. The journal in frame will be fitted with bearing made in four parts, having two side pieces, one top and one bottom piece, and provided with adjustments for taking up wear.

The bearing will be lined with babbitt metal, expanded in place, and bored and scraped to fit the shaft, and provided with suitable oil channels to effect an even distribution of oil over the entire surface of the journal.

Slide.—The slide will be rigidly bolted at the ends to cylinder and frame. The ends of slide will be recessed into cylinder and frame, so as to hold slide accurately in alignment. The slide will be bored where crosshead travels. The bored slide reduces the chances of hot journals, by allowing the crosshead to travel in any path required by the crank pin, should the engine get out of level through settling of the foundation.

Crosshead.—The crosshead will be made of cast iron, polished on the bosses, and furnished with babbitt face, removable and adjustable shoes, turned and scraped to fit the bored slide.

The crosshead pin will be fitted into crosshead with a taper fit, and held in place by a heavy steel nut, so that it can be easily removed without dismantling the engine; size of crosshead pin ————————.

Shaft.—The crank shaft will be ————inches diameter and made of iron, hammered from selected scrap. The reduction from the diameter in the center to the diameter of journals, will be made with long fillets.

Wheel.—The balance wheel on the engine will be———— feet diameter ————inches face. Weight approximately ————pounds. The wheel will be made in———— and so designed that it may be run at a much greater speed than specified and will be so proportioned that the strains

Corliss Engines, Continued.

arising from centrifugal force will be far below the elastic limit of the material employed. Wheels 10 feet diameter and under are made in one piece, unless otherwise specified.

Crank.—The crank will be of our counterbalanced type pressed on shaft and keyed in place. The crank pin will be forced in crank and riveted over; size ————————.

Connecting Rod.—The connecting rod will be made of open hearth steel, with solid crosshead end and bolted strap crank end with wedge adjustment for taking up wear. Ends of rods will be fitted with bronze boxes, bored and scraped to fit the pins. The crank-pin end will be lined with babbitt.

Piston.—The piston will be made of cast iron, heavily ribbed inside, and have follower, bull rings and packing rings. The piston will be constructed so that the rings may be inspected or replaced without removing the piston from cylinder, or taking it from piston rod. The bull rings will cover entire face of piston so that no wear will come on piston itself.

Piston Rod.—The piston rod will be made of open hearth steel, finished and polished, and secured to crosshead by thread and jam nut.

Press Fits.—The crank pin and crank will be forced in place. No shrink fits will be used on any part of the engine.

In General.—It is the intention of this specification to cover the construction of an engine, complete in every respect, as specified. All material and workmanship to be strictly first-class.

All the rough parts to be filled, rubbed down to a fair and uniform surface, then painted with one coat of shop paint before shipping. No ornamental painting is included in these specifications.

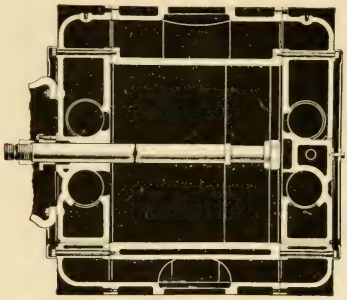
With the engine will be furnished a full set of foundation bolts and washers, throttle valve, sight feed cylinder lubricator or automatic oil pump with pipe to connect, oilers for main journal, center crank pin oiler and wiper cup for cross head pin. Also supply wrenches for the parts of engine that require adjustment. No steam or exhaust piping or flanges will be furnished unless specified.

The purchaser is to furnish the foundation according to plan and such sub-foundation (for which shop does not furnish plans), as the conditions require, do all mason and carpenter work, furnish material for and make all pipe connections.

Corliss Engines, Continued.

Remarks on Specifications.

On pages 614–617, under the head of "Economy," mention has been made of a number of deviations from standard specifications, in the nature of refinements that tend toward the greatest economy.



(Longitudinal Section Through Horizontal Cylinder, Showing Valves in the Cylinder Heads.)

(Note the minimum amount of clearance possible, but desirable only on vertical engines.)

Among other **deviations from the standard** may be mentioned the following:

Double Eccentrics instead of Single Eccentrics, the Admission and Exhaust Valves being actuated by Independent Eccentrics.

Steel Crossheads.

Suitable Oil Guards of polished brass or sheet steel for both the cranks and the eccentrics.

The Admission of Steam into the Bottoms of the Cylinders instead of the Top (which is the usual practice), in which event the valves are furnished with Polished Hand Wheels and Floor Stands.

A safety Stop Motion placed in the main steam pipe, with suitable liberating device controlled by an independent governor, arranged to shut off steam in case the engine from any cause has a tendency to run above its normal speed.

An Engine Type Clock and a Revolution Counter can also be put on the gauge board when desired.

Cast Iron Plates under the Cylinders and Frames, doing away with the need of stones in the foundation.

Auxiliary and Safety Stops on the Governor.

Steam Jackets on the Cylinders; etc., etc.

Corliss Engines, Continued.

Remarks on Specifications, Continued.

Rule for Calculating Sizes of Bearings.

Bearings are usually calculated upon a basis of 130 lbs. weight per square inch of projected area, though 140 to 150 lbs. are allowed in some cases. The character of the work determines which one of these figures should be taken.

In explanation of the above, it is perhaps well to state that by the term "projected" area is meant the area of the bearing projecting on a horizontal plane through its center; in other words, the diameter of the shaft multiplied by the length of the bearing; and is to be carefully distinguished from actual area, which would mean one-half the circumference of the shaft, multiplied by the length of the bearing.

Each bearing is figured as carrying one-half the load.

Rules for Calculating Wheels for Direct Connection to A. C. Generators, Running in Parallel.

$$WR^2 \text{ \& } Gr^2 = 440{,}000{,}000 \frac{HP}{N^3} fp.$$

W—Weight of fly wheel.
R—Radius of gyration of fly wheel in feet .4 diameter of wheel.
G—Weight of generator.
r—Radius of gyration of generator in feet.
HP—Horse power at normal load.
N—Number of revolutions per minute.
P—Number of poles in generator.
f—Variable factor, depending upon the type of engine, values of which are given in the following table:

Type of Engine.	For Variable Load.	For Steady Load.
Single Machine	.3	.22
Tandem Compound	.25	.18
Cross Compound	.20	.15
Vertical Hor. Compound, single	.20	.15
Vertical Hor. Compound, twin	.10	.10
Twin Tandem Compound	.20	.15

Use regular wheels when this formula gives lighter than regular wheels.

For direct connection wheels are built with heavy rims square in cross section. They are generally designed for a belt speed not to exceed a mile per minute. The arms of well-proportioned wheels should be oval in cross section so as to bring the air friction to a minimum.

Corliss Engines, Continued.

Remarks on Specifications, Continued.

Engine Requirements for Parallel Operation of Engine Type or Direct-Connected Alternators.

(Westinghouse Electric & Manufacturing Co.)

Engines driving alternators should have the following characteristics:

A.—The engine governors should be so constructed that there is no tendency to cause a periodic transfer or surging of the load between one engine and another. This tendency may originate in the angular variation of velocity in different parts of the revolution which is common to all reciprocating engines, or to a sudden variation of load which will affect each govenor in a slightly different manner, or to other causes that lead to a non-uniform speed. The engine governors should not be sensitive to such disturbances nor maintain or increase them.

The effect on the engines of a periodic transfer of load occasioned by hunting between two engines running in parallel is somewhat similar in effect to throwing the load on or off of a single engine at short equal intervals which may be measured by one or several pulsations in the combined turning efforts applied to the engine shaft.

In some extreme conditions the pulsations of load may amount to more than the normal capacity of either engine. With no external load one engine may then alternately drive the other, which will evidently be a more severe condition than if the load were only applied and removed from a single engine.

If under any case of pulsating load the engines do not tend to accentuate the pulsations in turning effort and speed, then a condition favorable to parallel running is attained.

B.—Variation of the rotating part of the generator through the revolution at any constant load not exceeding 25 per cent. overload should not exceed one-sixtieth of the pitch angle between two consecutive poles from the position it would have if the motion were absolutely uniform at the same mean velocity. The maximum allowable variation, which is the amount the rotating part forges ahead plus the amount which it lags behind the position of uniform rotation, is therefore one-thirtieth of the pitch angle between two poles. Generally this is obtained by the use of a heavy fly-wheel.

Corliss Engines, Continued.

Remarks on Specifications, Concluded.

Engine Requirements for Parallel Operation, Concluded.

In a 2-pole machine this variation is equivalent to 3° as measured on the circumference of the rotating part; in a 4-pole machine it is 1½°, and in a 6-pole 1°, or as the number of poles increases the permissible angular variation decreases.

C.—The engines should have practically the same characteristics of speed regulation that the power delivered to their respective generators may be proportional to the load; that is, the same load on any engine should produce the same percentage drop in its speed. This is most readily obtained in engines in which at full load the speed drops from 3 to 5 per cent. below the no-load speed, as a slight change in adjustment of the governor will have less relative effect than in engines in which the speed drops only 1 per cent. under the same variation of load.

D.—The use of governors which are adjustable while the engine is running is recommended. Slight adjustments of speed may then be made which will facilitate synchronizing the alternators or changing the load carried by the engines.

Maximum Permissible Variation on Either Side of Uniform Rotation.

Poles.	Angular Degrees.	Per Cent. of Circumference.	Poles.	Angular Degrees.	Per Cent. of Circumference.
2	3.000	0.8330	42	0.143	0.0395
4	1.500	0.4160	44	0.136	0.0380
6	1.000	0.2770	46	0.130	0.0360
8	0.750	0.2080	48	0.125	0.0345
10	0.600	0.1660	50	0.120	0.0335
12	0.500	0.1300	52	0.115	0.0320
14	0.430	0.1190	54	0.111	0.0310
16	0.375	0.1040	56	0.107	0.0295
18	0.333	0.0920	58	0.103	0.0285
20	0.300	0.0835	60	0.100	0.0280
22	0.270	0.0750	62	0.097	0.0270
24	0.250	0.0690	64	0.094	0.0260
26	0.230	0.0640	66	0.091	0.0250
28	0.210	0.0595	68	0.088	0.0245
30	0.200	0.0555	70	0.086	0.0240
32	0.187	0.0520	72	0.083	0.0230
34	0.177	0.0490	74	0.081	0.0225
36	0.167	0.0465	76	0.079	0.0217
38	0.158	0.0440	78	0.077	0.0211
40	0.150	0.0415	80	0.075	0.0206

WESTINGHOUSE CORLISS ENGINES.

The foregoing pages, with the exception of the illustrations on pages 611, 612, 614 and 618, refer to the average type of engines built by the many different builders of this class of engines in this country. Unfortunately for the character of the work, competition in this line has been keen, and there has been a constant tendency toward cheapening these machines to the very great detriment of the character of the work furnished.

Most builders have but a few sizes of patterns, which may be said to be classified under the general term of standard engines and built to standard specifications. This is the type of machine heretofore considered.

The Westinghouse Machine Company, however, have steadily refused to have their hand forced, and have confined their attention exclusively to building engines to suit the special conditions for which they are ordered. They have no standard sizes and carry no engines in stock. Every engine is designed and built for the specific purpose for which it is purchased. These machines represent the highest type of workmanship of its class obtainable, and even though the prices are not competitive with the class of engines heretofore described, there are customers who want the best that can be had, and I therefore list in the following pages a limited amount of data pertaining to them.

Table of Sizes and Details,
Horizontal Non-Condensing Engines.

Size of Engine, in Inches.		Maximum Revolutions per Minute.	Size of Pipes In Inches.		Size of Wheels Usually Furnished.	
Cylinder.						
Diameter.	Stroke.		Steam.	Exhaust.	Diameter, in Feet.	Face, in Inches
Single Cylinder—Belted.						
16	30	135	5	7	11	20
16	36	130	5	7	11	22
18	30	135	6	8	11	25
18	36	130	6	8	11	32
20	36	120	6	8	12	34
20	42	115	6	8	12	39
22	36	120	7	9	12	41
22	42	115	7	9	12	48
24	42	105	8	10	14	48
24	48	100	8	10	14	55
26	42	105	9	10	14	57
26	48	100	9	10	15	56
28	42	105	10	12	15	63
28	48	100	10	12	16	65
30	42	105	10	12	15	70
30	48	100	10	12	16	75
32	48	95	12	14	16	84
32	54	88	12	14	17	89
34	48	95	12	14	16	94
32	54	88	12	14	17	99
Single Cylinder—Direct Connected.						
12	30	135	4	5	14	
12	36	130	4	5	15	
14	30	135	4	6	14	
14	36	130	4	6	15	
16	36	120	5	7	16	
16	42	115	5	7	17	
18	36	120	6	8	16	
18	42	115	6	8	17	
20	42	105	6	8	18	
20	48	100	6	8	18	
22	42	105	7	9	18	
22	48	100	7	9	18	
24	42	105	8	10	18	
24	48	100	8	10	18	
26	42	105	9	10	18	
26	48	100	9	10	18	
28	48	95	10	12	20	
28	54	88	10	12	22	
30	48	95	10	12	20	
30	54	88	10	12	22	

Single cylinder belted engines to operate with not more than 120 pounds team, non-condensing. List includes double eccentrics, double ported valves, drip pan under valve gear, crank and eccentric oil casings. Wheels based on 120 pounds steam, one-fifth cut-off.

Single cylinder direct connected engines are designed for maximum pressure of 160 pounds, non-condensing. List includes double ported valves, double eccentrics, crank and eccentric oil casings, drip pans only under valve gear. Fly wheels are approximate for D. C. or 25 cycle work. Wheels 18′ diameter and over, made in segments, all others made in halves.

For Horse Powers, see pages 620-1.
Diagrams and Dimensions, see pages 648-651.

Table of Sizes and Details, Horizontal Compound Engines.

***Direct Connected Heavy Duty Type.**

Cylinder Ratio 4 to 1.

Size of Engine, in Inches.			Maximum Revolutions per Minute.	Sizes of Pipes in inches.		Diameter in Feet of Wheels Usually Furnished.
H. P. Cylinder.	L. P. Cylinder.	Stroke.		Steam.	Exhaust.	
Tandem Compound Condensing.						
12	24	36	120	4	10	16
12	24	42	115	4	10	17
14	28	36	120	4	12	16
14	28	42	115	4	12	17
16	32	42	105	5	14	18
16	32	48	100	5	14	18
18	36	42	105	6	14	18
18	36	48	100	6	14	18
20	40	42	105	6	16	18
20	40	48	100	6	16	18
22	44	42	105	7	18	18
22	44	48	100	7	18	18
24	48	48	95	8	20	20
24	48	54	88	8	20	22
26	52	48	95	8	22	20
28	56	54	88	9	22	22
Cross Compound Condensing.						
12	24	30	135	4	10	14
12	24	36	130	4	10	15
14	28	30	135	4	12	14
14	28	36	130	4	12	15
16	32	36	120	5	14	16
16	32	42	115	5	14	17
18	36	36	120	6	14	16
18	36	42	115	6	14	17
20	40	42	105	6	16	18
20	40	48	100	6	16	18
22	44	42	105	7	18	18
22	44	48	100	7	18	18
24	48	42	105	8	20	18
24	48	48	100	8	20	18
26	52	42	105	9	22	18
26	52	48	100	9	22	18
28	56	48	95	10	24	20
28	56	54	88	10	24	22
30	60	48	95	10	24	20
30	60	54	88	10	24	22

*For belted type, use these same sizes with wheels of proper width of face to accommodate the requisite width of belt or number of ropes—see pages 349 and 363-4.

Engines listed above have double ported valves throughout, in cylinders; double eccentrics, crank and eccentric oil casings; receiver, and drip pans under valve gear. Fly wheels are approximate for direct current or 25 cycle A. C. work. Wheels 18 feet in diameter are made in segments, all others made in halves. Engines are designed to operate with 160 pounds steam at throttle and not more than 50 pounds receiver pressure.

For Horse Powers, see pages 622-4.
Diagrams and Dimensions, see pages 652-655.

Westinghouse Corliss Engines, Continued.

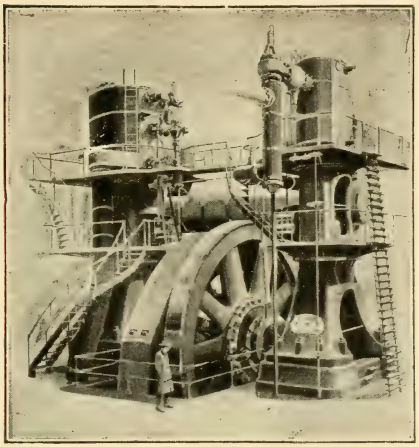


Table of Sizes and Details, Vertical Cross Compound Engines.

Direct-Connected Type.

(Cylinder Ratio 4 to 1.)

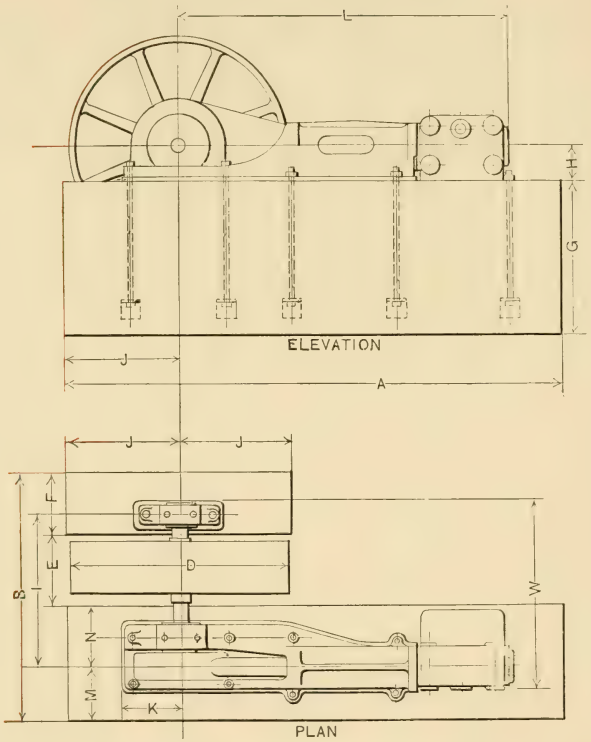
Size of Engine, in Inches.			Maximum Revolutions per Minute.	Sizes of Pipes in inches.		Diameter in Feet of Wheels Usually Furnished.
H. P. Cylinder.	L. P. Cylinder.	Stroke.		Steam.	Exhaust.	
24	48	48	90	8	18	18
26	52	48	90	9	20	18
28	56	48	90	10	24	18
30	60	48	90	10	24	18
30	60	54	85	10	24	23
32	64	54	85	12	24	23
34	68	54	85	12	26	23
36	72	54	85	12	28	23
38	76	54	85	12	28	23
38	76	60	75	12	28	23
40	80	60	75	14	28	23
42	84	60	75	14	28	25
44	88	60	75	14	28	28

For belted type use these same sizes with wheels of proper width of face to accommodate the requisite width of belt or number of ropes,—see pages 349 and 363-4.

For horse powers, see pages 622-4.

Diagram and Dimensions, see page 656

Westinghouse Corliss Engines, Continued.



Dimension and Foundation Diagrams.

Heavy Duty, Simple Non-Condensing Engines.

(Belted Type.)

Table of Lettered Dimensions

Heavy Duty, Simple Non-Condensing Engines.

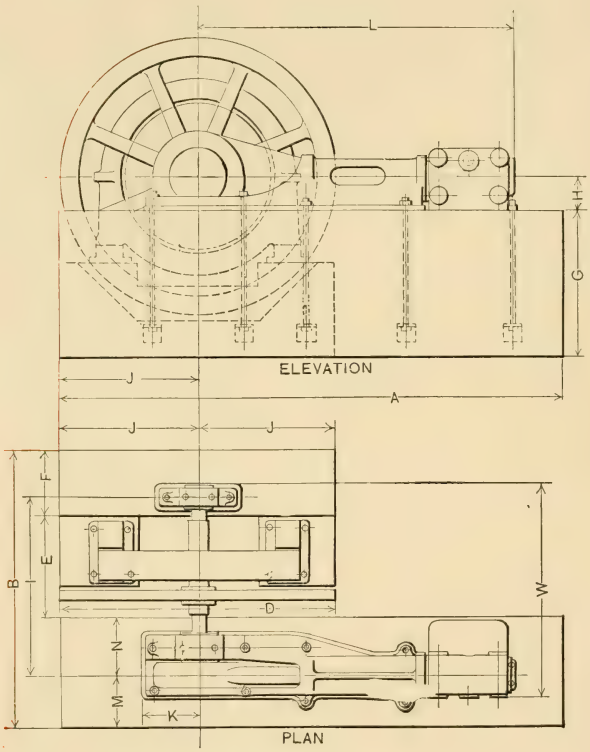
(Belted Type.)

Size of Engine.		Approximate Dimensions, in Feet and Inches.													
Diam-eter.	Stroke.	A	B	D	E	F	G	H	I	J	K	L	M	N	W
16	30	23-6	11-1	11-0	2-7	3-0	6-6	1-8	6-6	5-6	2-9	15-10	2-6	3-0	8-4
16	36	24-0	11-3	11-0	2-9	3-0	6-6	1-8	6-8	5-6	2-9	16-4	2-6	3-0	8-6
18	30	23-6	11-6	11-0	3-0	3-0	7-0	1-8	6-11	5-6	2-9	15-11	2-6	3-0	8-10
18	36	24-0	12-1	11-0	3-7	3-0	7-0	1-8	7-6	5-6	2-9	16-5	2-6	3-0	9-4
20	36	26-6	13-11	12-0	3-11	3-6	7-6	1-11	8-6	6-0	3-2	18-3	3-0	3-6	10-8
20	42	27-0	14-4	12-0	4-4	3-6	7-6	1-11	8-11	6-0	3-2	18-9	3-0	3-6	11-1
22	36	26-6	14-6	12-0	4-6	3-6	8-0	1-11	9-1	6-0	3-2	18-3	3-0	3-6	11-4
22	42	27-0	15-1	12-0	5-1	3-6	8-0	1-11	9-8	6-0	3-2	18-9	3-0	3-6	11-11
24	42	30-6	16-6	14-0	5-2	4-0	8-6	2-2	10-3	7-0	3-10	20-10	3-6	3-10	12-9
24	48	31-0	17-1	14-0	5-9	4-0	8-6	2-2	10-10	7-0	3-10	21-4	3-6	3-10	13-4
26	42	31-0	17-3	14-0	5-11	4-0	9-0	2-2	11-0	7-0	3-10	21-3	3-6	3-10	13-7
26	48	32-0	17-2	15-0	5-10	4-0	9-0	2-2	10-11	7-6	3-10	21-9	3-6	3-10	14-6
28	42	31-6	19-6	15-0	6-6	4-6	9-6	2-6	12-6	7-6	4-0	20-9	4-0	4-6	15-5
28	48	34-6	20-6	16-0	7-0	4-6	9-6	3-1	13-6	8-0	5-2	23-4	4-0	5-0	16-5
30	42	31-6	20-1	15-0	7-1	4-6	10-0	3-0	13-1	7-6	4-0	20-11	4-0	4-6	16-1
30	48	34-6	21-4	16-0	7-10	4-6	10-0	3-1	14-4	8-0	5-2	23-6	4-0	5-0	17-4
32	48	35-0	23-1	16-0	8-7	5-0	10-6	3-1	15-4	8-0	5-2	23-8	4-6	5-0	18-7
32	54	38-0	24-0	17-0	9-0	5-0	10-6	3-2	16-5	8-6	5-8	25-9	4-6	5-6	19-10
34	48	35-6	24-5	16-0	9-5	5-0	11-0	3-2	16-10	8-0	5-8	24-1	4-6	5-6	20-4
34	54	38-0	24-10	17-0	9-10	5-0	11-0	3-2	17-3	8-6	5-8	25-9	4-6	5-6	20-9

Note.—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purposes of installation.

See page 645 for sizes and details.

Westinghouse Corliss Engines, Continued.



Dimension and Foundation Diagrams.

Heavy Duty, Simple Non-Condensing Engines

(Direct Connected Type).

Table of Lettered Dimensions.

Heavy Duty, Simple Non-Condensing Engines.

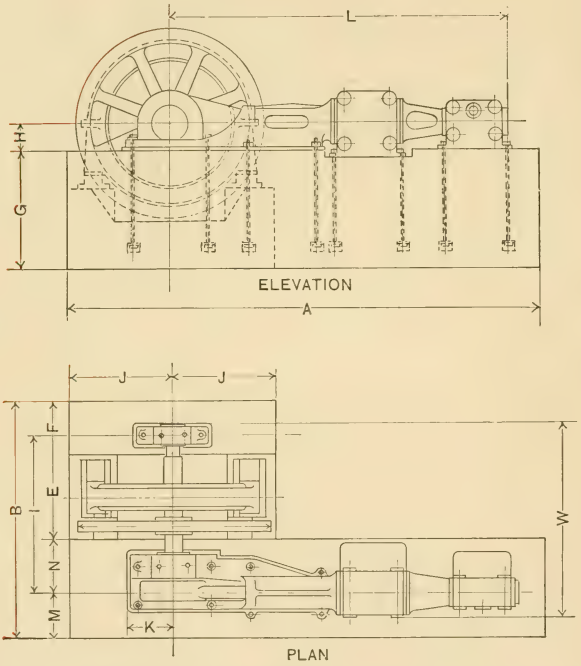
(Direct Connected Type.)

Size of Engine.		Approximate Dimensions, in Feet and Inches.													
Diam-eter	Stroke.	A	B	D	E	F	G	H	I	J	K	L	M	N	W
12	30	25-0	14-4	14-0	5-10	3-0	6-6	1-8	9-9	7-0	2-9	15-8	2-6	3-0	11-6
12	36	26-0	14-4	15-0	5-10	3-0	6-6	1-8	9-9	7-6	2-9	16-2	2-6	3-0	11-6
14	30	25-0	14-4	14-0	5-10	3-0	7-0	1-8	9-9	7-0	2-9	15-9	2-6	3-0	11-6
14	36	26-0	14-11	15-0	6-5	3-0	7-0	1-8	10-4	7-6	2-9	16-3	2-6	3-0	12-1
16	36	28-6	15-11	16-0	5-11	3-6	7-6	1-11	10-6	8-0	3-2	18-0	3-0	3-6	12-6
16	42	29-6	15-11	17-0	5-11	3-6	7-6	1-11	10-6	8-6	3-2	18-6	3-0	3-6	12-6
18	36	28-6	15-11	16-0	5-11	3-6	8-0	1-11	10-6	8-0	3-2	18-1	3-0	3-6	12-7
18	42	29-6	16-1	17-0	6-1	3-6	8-0	1-11	10-8	8-6	3-2	18-7	3-0	3-6	12-9
20	42	32-6	17-8	18-0	6-2	4-0	8-6	2-2	11-5	9-0	3-10	20-9	3-6	4-0	13-8
20	48	33-0	18-3	18-0	6-9	4-0	8-6	2-2	12-0	9-0	3-10	21-3	3-6	4-0	14-3
22	42	32-6	18-3	18-0	6-9	4-0	9-0	2-2	12-0	9-0	3-10	20-9	3-6	4-0	14-3
22	48	33-0	18-3	18-0	6-9	4-0	9-0	2-2	12-0	9-0	3-10	21-3	3-6	4-0	14-3
24	42	32-6	20-3	18-0	7-3	4-6	9-6	2-6	13-3	9-0	4-0	20-4	4-0	4-6	16-0
24	48	35-0	20-7	18-0	7-11	4-6	9-6	3-1	14-5	9-0	5-2	22-11	4-0	5-0	17-4
26	42	33-0	20-7	18-0	7-7	4-6	10-0	2-6	13-7	9-0	4-0	20-9	4-0	4-6	16-5
26	48	35-6	20-7	18-0	7-11	4-6	10-0	3-1	14-5	9-0	5-2	23-4	4-0	5-0	17-4
28	48	39-6	20-5	20-0	7-11	5-0	10-6	3-1	14-8	12-6	5-2	23-4	4-6	5-0	17-9
28	54	42-0	22-11	22-0	7-11	5-0	10-6	3-2	15-4	12-6	5-8	25-7	4-6	5-6	18-8
30	48	40-0	23-1	20-0	8-1	5-0	11-0	3-2	15-6	12-6	5-8	23-11	4-6	5-6	18-10
30	54	42-0	23-1	22-0	8-1	5-0	11-0	3-2	15-6	12-6	5-8	25-7	4-6	5-6	18-10

Note.—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purpose of installation.

See page 645 for sizes and details.

Westinghouse Corliss Engines, Continued.



Dimension and Foundation Diagrams.

Heavy Duty, Tandem Compound Condensing Engines.

(Direct Connected Type.)

Table of Lettered Dimensions.

Heavy Duty Tandem Compound Condensing Engines

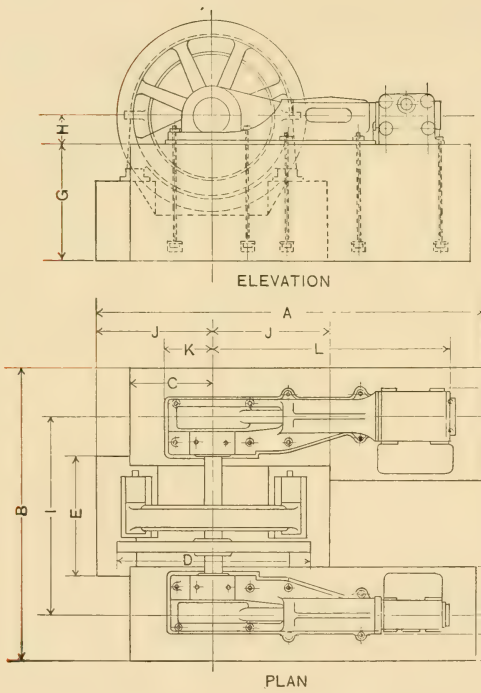
(Direct Connected Type.)

Size of Engine			Approximate Dimensions, in Feet and Inches.													
High Pressure Diameter.	Low Pressure Diameter.	Stroke.	A	B	D	E	F	G	H	I	J	K	L	M	N	W
12	24	36	36-6	15-10	16-0	5-4	3-6	8-6	1-11	10-5	8-0	3-2	25-8	3-0	4-0	12-8
12	24	42	38-0	16-2	17-0	5-8	3-6	9-0	1-11	10-9	8-6	3-2	26-8	3-0	4-0	13-0
14	28	36	36-6	16-3	16-0	5-9	3-6	8-6	1-11	10-10	8-0	3-2	25-9	3-0	4-0	13-4
14	28	42	38-0	16-3	17-0	5-9	3-6	9-0	1-11	10-10	8-6	3-2	26-9	3-0	4-0	13-4
16	32	42	41-6	18-0	18-0	6-0	4-0	9-6	2-2	11-10	9-0	3-10	29-6	3-6	4-6	13-6
16	32	48	42-6	18-6	18-0	6-6	4-0	10-0	2-2	12-4	9-6	3-10	30-6	3-6	4-6	14-0
18	36	42	41-6	20-0	18-0	7-0	4-0	9-6	2-6	13-2	9-0	4-0	29-5	4-0	5-0	16-3
18	36	48	44-6	20-3	18-0	7-3	4-0	10-0	3-1	13-4	9-6	5-2	32-6	4-0	5-0	16-5
20	40	42	43-0	20-9	18-0	7-3	4-6	10-0	2-6	13-8	9-6	4-0	30-2	4-0	5-0	17-0
20	40	48	46-0	21-4	18-0	7-4	4-6	10-6	3-1	13-10	10-0	5-2	33-3	4-6	5-0	17-2
22	44	42	44-0	22-2	18-0	7-8	4-6	10-6	2-8	14-8	10-6	4-7	30-2	4-6	5-6	18-2
22	44	48	47-6	22-6	18-0	8-0	4-6	11-0	3-1	15-3	11-0	5-2	33-4	4-6	5-6	18-9
24	48	48	48-6	24-6	20-0	8-0	5-0	11-0	3-1	16-3	11-0	5-2	34-1	5-0	6-6	20-3
24	48	54	51-6	24-6	22-0	8-0	5-0	12-0	3-2	16-3	11-6	5-8	36-9	5-0	6-6	20-3
26	52	48	49-6	24-8	20-0	8-2	5-0	11-6	3-2	16-6	11-6	5-8	34-10	5-0	6-6	20-8
26	52	54	55-6	25-6	22-0	9-0	5-0	12-0	3-2	17-4	12-0	5-8	37-2	5-0	6-6	21-6

Note.—These tables should be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purposes of installation.

See page 646 for sizes and details.

Westinghouse Corliss Engines, Continued.



Dimension and Foundation Diagrams.

Heavy Duty, Cross Compound Condensing Engines.

(Direct Connected Type.)

Table of Lettered Dimensions,

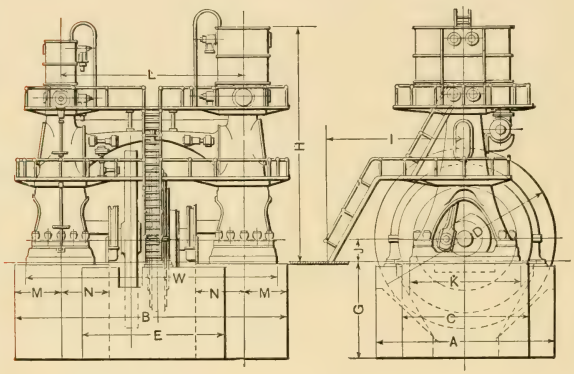
Heavy Duty, Cross Compound Condensing Engines.

(Direct Connected Type.)

Size of Engine.			Approximate Dimensions, in Feet and Inches.																
High Pressure Diameter.	Low Pressure Diameter.	Stroke.	A	B	C	D	E	G	H	I	J	K	L	M	N	O	P	Q	W
12	24	30	26-0	18-9	5-6	14-0	8-0	8-6	1-8	12-9	7-6	2-9	15-11	3-0	3-6	5-0	11-1	4-8	15-5
12	24	36	27-0	19-2	6-0	15-0	8-0	9-0	1-8	13-2	8-0	2-9	16-5	3-0	3-6	5-0	12-6	4-10	15-10
14	28	30	26-6	19-4	5-6	14-0	8-0	8-6	1-8	13-4	8-0	2-9	15-11	3-0	3-6	5-0	12-6	4-10	16-2
14	28	36	27-0	19-4	6-0	15-0	8-0	9-0	1-8	13-4	8-0	2-9	16-5	3-0	3-6	5-0	12-6	4-10	16-2
16	32	36	30-0	22-0	6-6	16-0	9-0	9-6	1-11	15-0	9-0	3-2	18-3	3-6	4-0	5-6	14-3	5-0	18-2
16	32	42	30-6	22-6	6-6	17-0	9-6	10-0	1-11	15-6	9-0	3-2	18-9	3-6	4-0	5-6	14-3	5-6	18-8
18	36	36	30-6	22-6	6-6	16-0	9-6	9-6	1-11	15-6	9-0	3-2	18-7	3-6	4-0	5-6	14-3	5-6	18-11
18	36	42	31-0	22-6	7-0	17-0	9-6	10-0	1-11	15-6	9-0	3-2	19-1	3-6	4-0	5-6	14-3	5-6	18-11
20	40	42	34-0	25-0	7-0	18-0	10-0	10-6	2-2	17-0	9-6	3-10	21-2	4-0	4-6	6-0	14-3	5-11	20-8
20	40	48	35-6	25-0	7-6	20-0	10-0	11-0	2-2	17-0	10-6	3-10	21-8	4-0	4-6	6-0	17-0	5-11	21-8
22	44	42	35-0	25-0	7-0	18-0	10-0	10-6	2-2	17-0	10-6	3-10	21-3	4-0	4-6	6-0	17-0	5-11	21-0
22	44	48	37-6	25-0	7-6	20-0	10-0	11-0	2-2	17-0	12-6	3-10	21-9	4-0	4-6	6-0	21-6	5-8	21-0
24	48	42	35-6	28-0	7-6	18-0	11-0	11-0	2-6	19-0	12-6	4-0	20-10	4-6	5-0	6-6	21-6	5-8	23-5
24	48	48	39-6	28-6	8-0	20-0	11-0	11-6	3-1	19-6	12-6	5-2	23-6	4-6	5-6	6-6	21-6	5-8	24-0
26	52	42	36-6	29-0	8-0	18-0	11-0	11-0	2-6	19-0	12-6	4-0	21-1	5-0	5-6	6-6	21-6	5-8	23-8
26	52	48	39-0	30-6	8-6	20-0	11-0	11-6	3-1	20-6	11-6	5-2	23-8	5-0	5-6	6-6	18-7	6-9	25-3
28	56	48	39-6	31-4	9-0	20-0	12-0	12-0	3-1	21-4	11-6	5-2	24-2	5-0	6-0	7-0	18-7	6-9	26-2
28	56	54	42-0	31-10	10-0	22-0	12-0	12-6	3-2	21-10	12-0	5-8	26-0	5-0	6-0	7-0	20-4	7-0	26-9
30	60	48	40-6	32-10	10-0	20-0	12-0	12-0	3-2	21-10	12-0	5-8	24-3	5-6	6-0	7-0	20-4	7-0	26-11
30	60	54	42-0	32-10	10-0	22-0	12-0	12-6	3-2	21-10	12-0	5-8	26-0	5-6	6-0	7-0	20-4	7-0	26-11

Note.—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purposes of installation.

Westinghouse Corliss Engines, Continued.



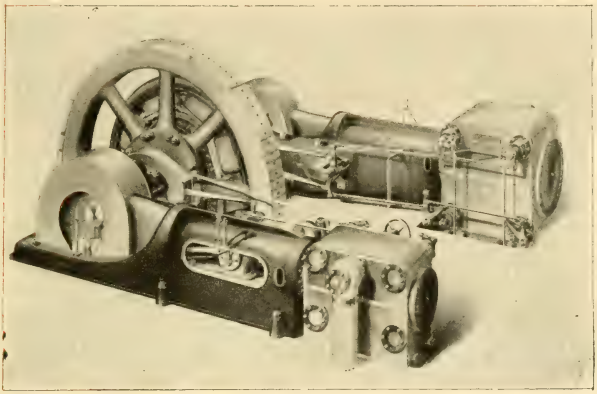
Diagrams and Table of Lettered Dimensions,

Vertical Cross Compound Condensing Engines.

(Direct Connected Type.)

Size of Engine.			Approximate Dimensions, in Feet and Inches.													
Diameter High Pressure.	Diameter Low Pressure.	Stroke.	A	B	C	D	E	G	H	I	J	K	L	M	N	W
24	48	48	23–0	26–0	13–0	18–0	15–6	11–6	26–0	14–0	2–10	10–4	18–0	4–3	4–4	24–6
26	52	48	23–0	26–0	13–0	18–0	15–6	11–6	26–2	14–0	2–10	10–4	18–0	4–3	4–4	24–6
28	56	48	23–0	28–0	13–0	18–0	17–6	11–6	26–6	14–0	2–10	10–4	20–0	4–3	4–4	26–6
30	60	48	23–0	29–0	13–0	18–0	18–6	11–6	26–9	14–0	2–10	10–4	21–0	4–3	4–4	27–6
30	60	54	23–6	34–6	16–0	23–0	19–0	13–0	36–0	17–0	3–0	13–0	24–6	5–6	5–10	32–6
32	64	54	23–6	34–6	16–0	23–0	19–0	13–0	36–6	17–0	3–0	13–0	24–6	5–6	5–10	32–6
34	68	54	23–6	35–0	16–0	23–0	19–0	13–0	30–6	17–0	3–0	13–0	25–0	5–6	5–10	33–0
36	72	54	24–0	37–0	18–0	23–0	19–6	13–6	31–4	17–0	3–4	15–2	26–0	5–6	6–4	35–1
38	76	54	24–0	37–0	18–0	23–0	19–6	13–6	31–4	17–0	3–4	15–2	26–0	5–6	6–4	35–1
38	76	60	29–6	38–0	18–6	23–0	20–0	14–0	33–5	18–0	3–6	15–10	26–6	5–9	7–0	36–0
40	80	60	31–0	38–6	18–6	23–0	20–0	15–0	33–5	18–0	3–6	15–10	27–0	5–9	7–0	36–6
42	84	60	33–0	39–6	19–0	25–0	21–0	16–0	34–9	18–0	3–11	16–3	27–6	6–3	7–2	37–8
44	88	60	34–0	40–0	19–0	28–0	21–3	16–0	34–9	20–0	3–11	16–3	28–0	6–3	7–2	38–2

Westinghouse Corliss Engines, Continued.



(Direct Connected Cross Compound.)

Sample Specification.

(For Heavy Duty Compound Engine.)

General Description.—The engine to be of the horizontal cross (or tandem) compound heavy duty condensing type, adapted for driving ————————.

The engine is to have a releasing or trip valve gear, and the inlet and exhaust valves on both high and low pressure cylinders are to be of the rolling type commonly called "Corliss."

Capacity.—It is understood that the engine is to operate condensing under the following conditions:

Steam pressure at throttle (gauge) ———— lbs.
Vacuum in exhaust pipe at Low Pressure Cylinder by mercury column ———— ins.
Revolutions per minute ————

Under the above conditions the normal rating of the engine will be ———— Indicated Horse Power. The engine will, however, be strong enough in all its parts to develop ———— per cent. overload continuously.

Design, Workmanship and Material.—The workmanship is to be first-class throughout.

The materials are to be of high grade, and in kind conforming to the most approved practice as regards each individual piece entering into the construction of the engine.

All castings will be true to pattern, of requisite thickness, and will bear close inspection for shifting of cores.

All joints will be carefully machined and accurately fitted.

Wherever "Air Furnace" or "Gun" iron is mentioned in this specification, it is understood to mean cast iron melted in an open hearth or air furnace, and to have the following physical characteristics:

(a) A cast test specimen 1 inch square resting on supports 12 inches apart shall be capable of sustaining a load of not less than 3000 pounds applied midway between the supports.
(b) A turned specimen shall show an ultimate tensile strength of not less than 30,000 pounds per square inch of cross section.

Westinghouse Corliss Engines, Continued.

Wherever "Cupola" iron is mentioned in this specification, it is understood to mean cast iron melted in the ordinary foundry cupola, and to have the following physical characteristics:

(a) A cast test specimen 1 inch square resting on supports 12 inches apart shall be capable of sustaining a load of not less than 2000 pounds applied midway between the supports.

(b) A turned specimen shall show an ultimate tensile strength of not less than 20,000 pounds per square inch of cross section.

Steel Castings.—Are to contain 0.20 per cent. to 0.25 per cent. carbon and to show the following physical characteristics in a standard test specimen 2 inches long and 1-2 inch diameter:

(a) Tensile strength not less than 65,000 pounds
(b) Elastic limit not less than 30,000 pounds
(c) Elongation not less than 15 per cent.

Steel Forgings.—Wherever mentioned in this specification, are to be understood as being made of the best quality of open hearth steel. The carbon in the steel may vary between 0.25 per cent. and 0.45 per cent. depending on the character of the forging. Irregular shapes in which the reduction of cross sectional area in forging is not reasonably uniform are to be made from the lower carbon steel. The other principal elements are to be as follows:

Sulphur not to exceed .....0.04 per cent.
Phosphorus not to exceed .....0.04 per cent.
Manganese, about .....0.60 per cent.
Silicon about .....0.20 per cent.

The physical characteristics will vary with the percentage of carbon present, but as exhibited in a standard test specimen 2 inches long and 1-2 inch diameter shall be within the following limits:

(a) Tensile strength not less than .....60,000 pounds
(b) Elastic limit not less than .....30,000 pounds
(c) Elongation not less than ..... 20 per cent.

Bearing Metal.—To be of best quality of babbitt metal or other anti-friction metals best suited for the conditions of use.

The machine as a whole will be heavy and strong and specially designed for the work. The shop reserves the right to make such changes in sizes and details of parts as in their judgment will give the best results, both in economy and durability, such changes not to affect the general design of the engine nor in any way modify the guarantees.

Frame.—The frame is to be of massive construction with board bearing surface, and is to rest throughout its entire length on foundation. The design is to be such as to give the best possible disposition of the metal to resist all strains effectively.

The bottom of the frame is to be finished off with an oil retaining lip to protect the foundation and floor. The frame is to be of the bored guide type and is to consist of a single casting which includes both guides and main journal bearing with a depression in bottom to collect oil thrown off by crank pins, journals and slides.

The flange and the slides are to be faced and bored at one setting to insure perfect alignment between cylinder and slides.

Main Shaft Journals.—Diameter and length to be as hereinafter set forth. They are to be fitted with cast iron adjustable boxes and lined with babbitt metal hammered in and bored to fit the shaft.

The shells are to be firmly held in place by heavy caps interlocking with the frame casting and forming a strong tie above the center of the shaft.

The bottom shell to be designed so as to be easily removable without sliding on the shaft when the weight on the journal is relieved.

Cylinders—To be made of air furnace iron of close grain and as hard as is consistent with good machine work.

The cylinder walls are to be sufficiently thick that when the cylinders are rebored to 1-2 inch larger diameter, the tensile strain on the

Westinghouse Corliss Engines, Continued.

metal will not exceed 2,000 pounds per square inch of cross section with pressures of 200 pounds and 60 pounds in the high pressure and low pressure cylinders, respectively.

The cylinders will be made with the exhaust chamber separated by an air space from the cylinder barrels, thus reducing the internal condensation and temperature strains. Valve chambers to be in cylinders.

Cylinder Heads.—To be of air furnace iron, heavily ribbed. They are to be machined on the inner surfaces, and drilled and tapped for eye and jack bolts.

Each rear cylinder head to be provided with a false cover suitably finished.

Valves.—To be of air furnace iron, carefully fitted to seats, and accurately machined on the cutting edges.

Both steam and exhaust valves to be double ported, special attention being given in the design to insure easy working and durable valves.

Valve Gear.—The valve gear is to be of the Corliss liberating type. The admission and exhaust valves of each cylinder will be driven by separate eccentrics. The admission valves will have what is commonly called a "three quarter gear," and the exhaust valves will be actuated by a bell crank gear, thus avoiding objectionable weight and consequent inertia.

All valve gear connections will be steel rods, fitted with heads provided with means for taking up wear, and for adjusting length from center to center of journals.

The steam valves will be closed by vacuum dash pots.

Suitable valve setting marks will be placed on valves and cylinders.

The eccentrics will be of cast iron, split to facilitate removal from shaft. The eccentric straps will be lined with babbitt metal and carefully scraped to a fit on the eccentrics.

Special attention to be given to construct a valve gear that will operate smoothly and be free from undue noise.

Governor.—To be of the fly ball type provided with means for insuring copious lubrication on all joints, and provided with ample excess power to overcome increased friction of gear due to accidental shortage of oil, etc.

Governor head to be enclosed in a neatly designed case. The governor will be spring controlled, thus rendering possible a highly sensitive regulation and avoiding the tendency to "hunt" usually present with weighted governors.

Pistons.—To be machined all over, fitted with cast iron sectional packing, and drilled and tapped for eye bolts for convenience in handling. To have ample bearing surface and metal so disposed as to afford maximum strength in proportion to its weight.

Pistons to be fitted with anti-friction metal bands, expanded into dove-tailed grooves. This metal to be of a special composition shown by our experience to be best suited for this purpose.

Piston Rod Packing.—Piston rod stuffing boxes are to be designed for any type of packing supplied by the purchaser, provided the necessary information be supplied by the purchaser within two weeks of signing of contract.

Piston Rods.—To be open hearth steel forging, finished to diameter hereinafter given. They will be screwed into the cross heads and supplied with a jam nut. The outer ends will be taper fit supplied with suitable nuts and keepers for securing the pistons.

Cross Heads.—To be of cast steel with babbitt faced cast iron removable shoes adjustable by wedges. The shoes are to be driven positively by the cross head so as to throw no additional strain on

Westinghouse Corliss Engines, Continued.

the adjusting screws. The cross heads are to be threaded for the piston rods and taper bored and ground for the cross head pins.

Cross Head Pins.—To be open hearth steel forgings with ground taper fits in cross head.

A hole is to be drilled through the axis, with two additional holes at right angles making communication with the upper surface for oiling.

Connecting Rods.—To be of forged steel, solid end type, with wedge adjusted boxes.

The cross head pin boxes are to be of hard bronze, and the crank pin boxes of cast iron lined with babbitt metal.

The adjusting wedges to be so arranged that distance from center to center of pins will remain substantially constant.

Crank Pins.—To be forged from open hearth steel, and to finish to diameter and length stated. They are to have axial and radial oil holes to be served with centrifugal oilers.

Crank pins will be forced into cranks by hydrostatic pressure and ends riveted over.

Cranks.—To be balanced discs of air furnace iron forced on shaft by hydrostatic pressure and securely keyed.

Main Shaft.—To be forged from best quality open hearth steel, diameter at journal to be as set forth. Maximum diameter to be sufficient to meet the requirements of the service intended.

Changes in diameter to be by means of long fillets.

Fly Wheel.—The fly wheel will be made of air furnace iron and of dimensions and weight set forth.

It will be made in ———————— and secured by forged steel connections. The proportions of the parts and the use of air furnace iron are here combined to produce a wheel in which the normal strains arising from centrifugal force will be far below the elastic limit of the material employed.

Receiver.—A receiver of ample proportions will be furnished together with necessary connections from the exhaust nozzle on high pressure cylinder to the inlet nozzle on low pressure cylinder.

Suitable arrangements including a trap and connections to receiver will be provided for draining the receiver, and it will be fitted with a pop safety valve, as a protection against overstraining should the pressure be allowed to exceed 50 pounds gauge. A by-pass from steam pipe to receiver will be provided for convenience in starting.

Lubrication.—The following lubricating devices will be furnished:

Mechanically driven oil pump.
Hand oil pumps.
Centrifugal crank pin oilers.
Cross head pin oilers.
Large sight feed oil cups for main journals.
Large sized compression grease cups for eccentrics.

In addition will be furnished a full complement of grease cups and small oil cups for the valve gear and all auxiliary bearings.

Oil Guards.—Suitable oil guards will be provided around the cranks and eccentrics to prevent throwing of oil.

Guards to be of an improved pattern designed to present a neat and sightly appearance.

Lagging.—The cylinders, receiver, and all portions of the engine where radiation losses might occur are to be protected by suitable non-conducting covering.

The cylinders are to be covered with steel plate lagging neatly painted, and secured with polished binding strips and corner plates.

Painting.—All parts of the engine which are not polished will be

Westinghouse Corliss Engines, Concluded.

filled, rubbed down smooth and given a plain coat of shop paint before shipment.

Fittings.—The following fittings will be furnished:

Throttle valve.
One By-pass valve and piping from throttle to receiver.
Pop safety valve for receiver.
Gauge and name tablet with gauges.
One Low Pressure trap for draining receiver, with necessary connections to same.
Drain cocks at all points where water is liable to collect.
Set of wrenches for all points requiring adjustment.
Foundation bolts, nuts and washers.
Angle valves for indicator connections to cylinder.

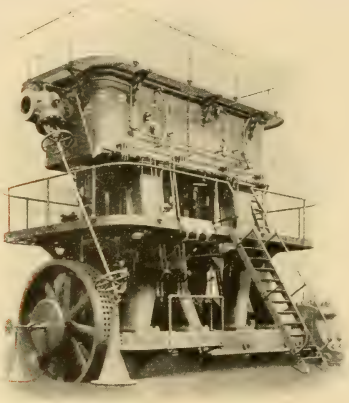
Regulation.—Between friction load and 25 per cent. overload the mean speed variation shall not exceed ———— per cent. either way from the normal speed.

Steam Consumption.—When operating under the conditions of steam pressure, vacuum and speed hereinbefore specified, the consumption of dry steam at point of best efficiency will not exceed ———— pounds per Indicated Horse Power per hour.

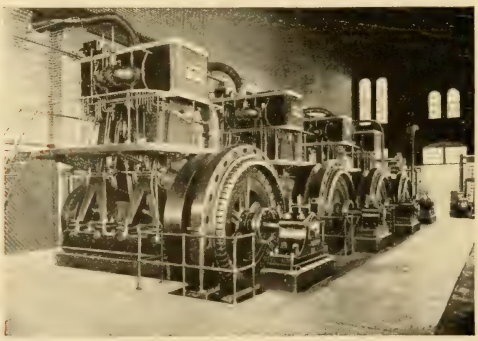
General Dimensions and Estimated Weights:

Diameter of High Pressure Cylinder		inches
Diameter of Low Pressure Cylinder		"
Stroke of Pistons		"
Diameter of Crank Pins		"
Length of Crank Pins		"
Length of Cross Head Pins		"
Diameter of Cross Head Pins		"
Diameter of Main Bearing		"
Length of Main Bearing		"
Diameter of High Pressure Piston Rod		"
Diameter of Low Pressure Piston Rod		"
Diameter of Steam Pipe		"
Diameter of Exhaust Pipe		"
Total Length of Engine, about	feet	"
Total Width of Engine, about	"	"
Diameter of Fly Wheel	"	"
Estimated Weight of Engine without Fly Wheel		lbs.
Estimated Weight of Fly Wheel		"
Total		"

WESTINGHOUSE MARINE TYPE COMPOUND ENGINES.



These engines are built in sizes up to 2,500 horse power. A vertical engine of high efficiency and compact design, especially adapted for moderate size power stations or for exciter units in large power stations. Adopted in the latter capacity by the Interborough Rapid Transit Company, New York City.

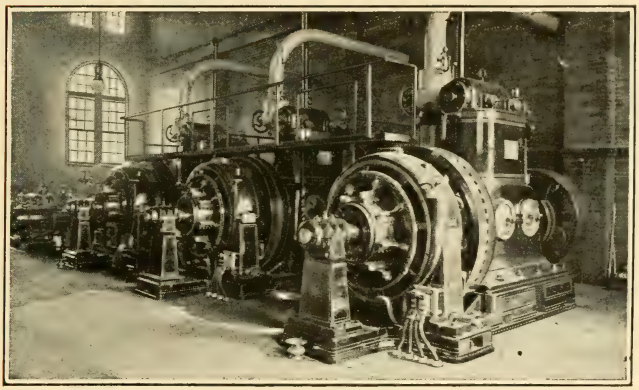


(Engine Room of the St. Louis Terminal, showing Marine Type Engine units).

WESTINGHOUSE HIGH SPEED INCLOSED TYPE ENGINES

(Automatic.)

For Electric Lighting, Power and Industrial Work.



(Westinghouse Compound Engines, driving D. C. Generators).

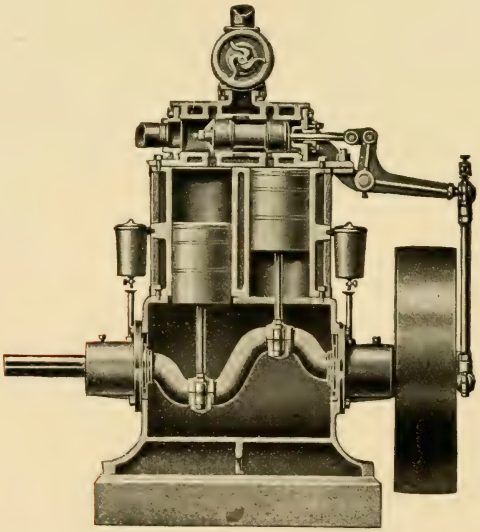
Three types of these engines are manufactured, Junior, Standard, and Compound—ranging from 5 to 400 H. P.,—all embodying the same mechanical principles and similar in all essential respects, but modified only for the special nature of the service contemplated in each.

In order that the performance of this type of engine may be compared with that of Corliss engines, I herewith append the following comparisons:

Westinghouse Junior and Standard Automatic Engines and all other non-compound single-valve engines, double or single-acting, less than 50 H. P.	34 to 38 lbs.
Ditto, over 50 H. P.	32 lbs.
Slow speed, releasing valve gear, non-condensing, single-cylinder engines of the Corliss type, 50 to 100 H. P.	28 to 35 lbs.
Ditto, 400 H. P. and upward, best recorded performances, non-condensing	26 to 28 lbs.
Ditto, condensing	19 to 21 lbs.
Westinghouse Compound Engine, non-condensing	*22 to 24 lbs.*
Westinghouse Compound Engine, condensing	*17 to 19 lbs.*

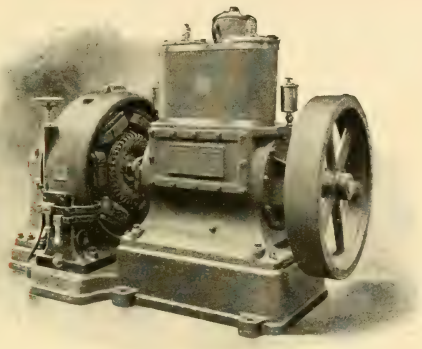
WESTINGHOUSE JUNIOR AUTOMATIC ENGINES.

The Westinghouse Junior Engine is built to supply a demand for a low priced automatic engine of durable construction and moderate economy. Its cost has been reduced through simplifying designs and construction and not by cheapening materials and workmanship.

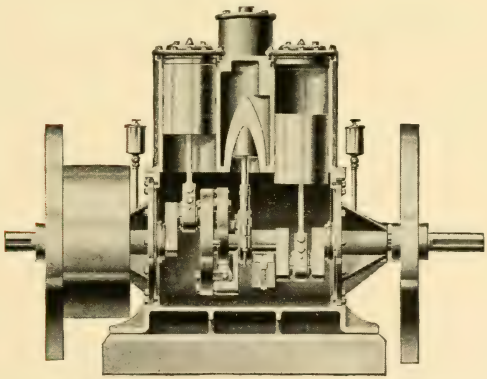


The governor is of the inertia type, located in the fly wheel. Throttling governing is used, however, as speed variation is necessary so as to drive condenser circulating pumps, etc. As shown in the above sectional elevation, the valve chest is located on top of the cylinder, thus reducing center to center distances between cylinders and doing away with little bearing. The valve is operated through belt crank from governor eccentric.

WESTINGHOUSE STANDARD AUTOMATIC ENGINES.



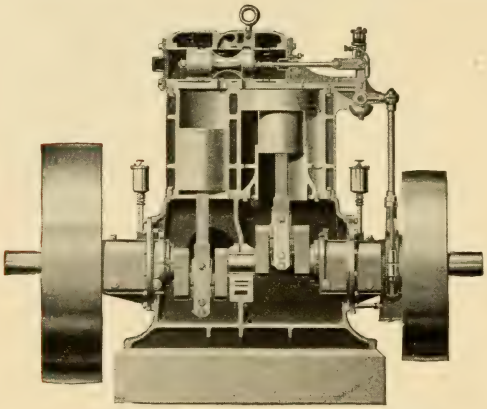
The Standard Engine, illustrated above as a direct connected unit, is built to meet the demand for the highest type of single acting enclosed automatic engine, by reason of its completely inclosed construction.



As shown above in the sectional elevation, this engine has either throttling or automatic inertia governor—the latter located inside the crank case. The governor springs are readily adjustable so that speed may be varied within small limits. Throttle control is used in stoker plants, etc., when variable speed is desired. Weight of valve is balanced by auxiliary piston.

WESTINGHOUSE COMPOUND AUTOMATIC ENGINES.

These engines, as illustrated on page 663, are, like the others of these types of engines, made either of the belted or direct connected type. While the Junior and Standard engines are essentially non-condensing simple engines, the compound is equally adapted for condensing or non-condensing operation.



As illustrated above in sectional elevation, there is an external inertia governor located in fly wheel and operating horizontal valve by belt crank; this valve controls steam distribution between both high and low pressure cylinders without riding cut-offs or other mechanism. The valve has renewable linings. There is no receiver between the cylinders. Cranks slotted out of solid metal at 180 degrees angularity balance the weights of the piston and keep an even turning movement. Steam distribution is such that the work is evenly divided between the cylinders. The connecting rod forms a single strut, there being no reversal of stresses taking place.

Westinghouse Automatic Engines, in General.

Many features are common to the three types:

(1). Inclosed crank case containing a mixture of oil and water into which the cranks dip.

(2). Plain vertical cylinders surmounting the crank case.

(3). Trunk pistons of generous length, double walled at the top to minimize the loss of heat.

(4). Balanced piston valves, spring packed, with removable liners.

(5). Bearings and shells mounted concentric with shaft in casing and removable in a single piece.

(6). Shafts forged solid.

(7). All wearing parts adjustable.

Westinghouse Automatic Engines, Continued.

The performance of these Engines and their sizes and details are seen from the following tables:

Steam Consumption of the Several Sizes of Westinghouse Automatic Engines as Determined by Actual Tests.

Size	Indicated Horse power	Steam per Indicated H. P. per Hour Lbs.	Size	Indicated Horse Power	Steam per Indicated H. P. per Hour Lbs.
Junior Engines.					
5 x 4	6.75	42.68	9 x 8	48.62	32.90
			"	25.47	31.42
6 x 5	16.73	41.21	"	14.11	34.61
"	9.42	42.14			
7 x 6	22.86	37.53	10 x 9	61.56	31.00
"	12.12	36.46	"	31.28	32.22
"	7.18	44.84	"	20.93	34.54
8 x 7	34.47	33.16	12 x 10	94.25	30.49
"	18.03	33.94	"	47.92	32.21
"	9.47	44.98	"	25.74	34.07
Standard Engines.					
4½ x 4	7.6	42.19	12 x 11	93.62	31.76
			12 x 11	60.41	30.06
			12 x 11	32.29	32.38
5½ x 5	14.7	40.37			
			13½ x 12	138.80	30.85
			13½ x 12	79.34	29.66
6½ x 6	23.75	38.76	13½ x 12	48.35	31.00
6½ x 6	13.02	37.78			
6½ x 6	8.51	42.30			
			14½ x 13	162.15	30.21
			14½ x 13	95.58	28.93
7½ x 7	36.25	34.99	14½ x 13	54.71	30.50
7½ x 7	19.02	36.80			
7½ x 7	11.03	41.56			
			15½ x 14	182.20	30.42
			15½ x 14	146.91	28.75
			15½ x 14	104.76	28.96
8½ x 8	47.23	34.55	15½ x 14	66.02	29.63
8½ x 8	25.12	34.60			
8½ x 8	15.40	42.70			
			18 x 16	208.73	26.63
			18 x 16	167.11	28.05
			18 x 16	125.44	28.24
9½ x 9	64.61	32.50	18 x 16	77.70	31.40
9½ x 9	36.15	30.95			
9½ x 9	20.60	34.00			
			20 x 16	315.12	27.75
			20 x 16	256.81	26.19
11 x 10	76.80	32.11	20 x 16	193.63	27.93
11 x 10	51.37	30.48	20 x 16	106.84	28.16
11 x 10	26.18	32.86	20 x 16	72.27	31.29

Steam Pressure 100 pounds. Cylinders Unjacketed. No Correction for Moisture in Steam.

Westinghouse Automatic Engines, Continued.

Table of Steam Consumed per Indicated Horse Power.

Compound Engine, Cylinders 14" and 24" x 14".

By Tests, Under Varying Loads and Pressures.

(Unjacketed and Uncorrected for Entrained Water, February, 1888).

Non-Condensing					Condensing			
Boiler Pressures				Horse Powers	Boiler Pressures			
60 lbs.	80 lbs.	100 lbs.	120 lbs.		120 lbs.	100 lbs.	80 lbs.	60 lbs.
			22.6	210	18.4			
		23.0	21.9	170	18.1	18.8		
	24.9	23.6	22.2	140	18.2	18.5	20.0	
	25.7	23.9	22.2	115	18.2	18.6	19.6	20.5
26.9	25.2	24.9	22.4	100	18.3	18.6	19.7	20.3
27.7	25.2	25.1	24.6	80	18.3	18.6	19.9	20.1
30.3	28.7	29.4	28.8	50	20.4	20.8	20.7	20.4

On page 663 we show an illustration of three generating sets, consisting of Westinghouse Compound Engines direct-connected to Westinghouse Multipolar Generators supplied for the light and power plant of the Union Station at Columbus, Ohio.

The tests were made with 150 pounds of steam, non-condensing, at five different loads, ranging from one-fifth up to full rated capacity of the engine, the results being tabulated below:

Electrical Output		Indicated Horse Power	Electrical Horse Power	Total Efficiency Engine and Dynamo Per Cent.	Steam Per Indicated Horse Power Per Hour	Steam Per Electrical Horse Power Per Hour
Amperes	Volts					
1000	125	202.56	167.56	82.72	22.82	27.59
810	125	162.48	135.72	83.53	23.23	27.81
610	125	124.67	102.21	82.00	24.31	29.65
400	125	81.35	67.02	82.40	28.06	34.06
200	125	46.69	33.57	71.75	35.21	49.06

List of Sizes and Details,

Westinghouse Single-Acting Automatic Engines.

Cylinders		Horse Power			Revolutions per Minute.	Piston Speed, Feet.	Piping		Space			Height to Centre of Shaft, Inches.	Fly Wheel	
Diameter, Inches.	Stroke, Inches.	80 lbs. Pressure.	90 lbs. Pressure.	100 lbs. Pressure.			Steam, Inches.	Exhaust, Inches.	Length, Inches.	Width, Inches.	Height, Inches.		Diameter, Inches.	Face, Inches.
Junior Engines.														
5	4	5	5·5	6	400	266	1½	2	43	20	39½	10¾	20	5
6	5	10	11	12.5	390	325	2	2½	51	22	49½	12	22	6
7	6	15	17	19	375	375	2½	3	59	28	57	14¼	28	7
8	7	25	28	31	360	420	3	3	63	32	61	15	32	8
9	8	35	40	44	350	466	3	3	70	36	68	16	36	9
10	9	50	56	62	350	525	3½	4	83	42	73	16½	42	10
12	10	75	84	93	330	550	4	4	96	48	84	18½	48	12
Standard Engines.														
4½	4	5	5·5	6	500	333	1½	1½	40	18	33	9¾	18	5
5½	5	10	11	12.5	500	417	2	2	47	21	35½	10½	21	6
6½	6	15	17	19	400	400	2	2	65	30	43½	12	20	8
7½	7	25	28	31	390	455	2½	2½	71	33	49½	14¼	22	9
8½	8	35	40	44	375	500	3	3	80	36	55	15¾	24	10
9½	9	45	50	55	350	525	3½	3½	88	42	61	16½	27	12
11	10	60	67	75	320	534	4	4	96	48	66½	18	30	13
12	11	75	84	93	300	550	5	5	107	52	72	20½	34	15
13½	12	100	113	125	300	600	6	6	117	60	83	22½	38	17
14½	13	125	140	156	290	628	6	6	130	66	88	24	40	21
15½	14	150	169	187	280	653	6	6	132	78	91	26	44	25
18	16	200	225	250	250	666	7	8	139	78	103	29	60	25
20	16	250	281	312	250	›	8	10	139	78	103	29	76	25

Atlanta, Ga., STUART W. CRAMER, Charlotte, N. C.

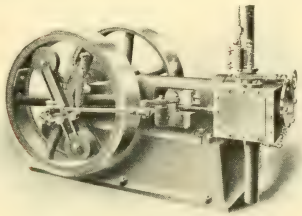
Westinghouse Automatic Engines, Concluded.

List of Sizes and Details,

Westinghouse Single-Acting Automatic Compound Engines.

Diameter Cylinders			Horse Power							Piping		Space			
High Pressure, Inches	Low Pressure, Inches	Stroke, Inches	100 lbs. Pressure	125 lbs. Pressure	150 lbs. Pressure	Add for Vacuum	Revolutions per Minute	Piston Speed, Feet	Pulley	Steam, Inches	Exhaust, Inches	Length, Feet and Inches	Width, Feet and Inches	Height, Feet and Inches	Height to Centre Shaft, Inches
8	13	8	35	45	55	7	375	500	To order as required	3	5	6– 7	3– 6	5– 2	16
9	15	9	50	65	80	10	350	525		4	6	7– 0	3– 8	5– 7	17½
10	18	10	65	85	100	14	320	533		4	6	8– 7½	4– 0	6– 1	18½
11	19	11	80	105	130	17	300	550		5	7	9– 1	4– 4	6– 5	20
12	20	12	100	130	160	20	300	600		5	7	9–11	4– 4	6–11	21½
13	22	13	125	160	200	25	290	628		6	8	10–10	4– 8	7– 5	23
14	24	14	150	200	250	31	280	653		6	8	11– 9	4– 8	7–11	25
16	27	16	200	260	330	40	250	666		8	10	12–10	6– 0	9– 2	28
18	30	16	250	330	410	51	250	666		8	10	14– 0	6– 0	9– 8	30

LIDDELL HORIZONTAL AUTOMATIC ENGINES.



(**Belted Type.**)

The High Speed Center-Crank Automatic Cut-Off Engine has now been on the market over twenty years, during which time every conceivable form of construction has been used. Some have stood the test of time and use ; many have not, and have been abandoned.

A manufacturer entering the High Speed Engine field late in the day has many advantages over the pioneers in the business ; he is not committed to any particular form of construction, but can select the type of valve best suited to the needs of his customers, the governor that will regulate the closest and be the most durable, the style of frame that is strongest and best adapted to continuous duty, etc.

The Liddell Engine was designed and built under the above named conditions, and the results given justify us, we believe, in claiming that no better engine of its class is made.

Piston.—The piston is made in one casting, cored out as light as possible, but abundantly strong to resist any ordinary strain. It is packed with two light snap rings, which are self-adjusting and easily and cheaply replaced when worn out.

Liddell Automatic Engines, Continued.

Valve.—The valve is of the flat-balanced type first used, we believe, by Professor Sweet on the Straight Line Engines, and has the following advantages, all of which are not possessed by any other type of valve:

1. It is light. 2. It does not leak. 3. It is perfectly balanced. 4. It has double steam and exhaust ports. 5. There is little or no wear in ordinary service. 6. It can leave its seat to relieve the engine of water. 7. Wearing down by its weight will not cause leakage over the top of valve as with piston valves. 8. It can be refitted by any good machinist without sending to the shop or by the use of special tools.

Valve Gear.—The valve gear is light, but abundantly strong, as the valve is perfectly balanced. By the use of the outside connected governor all parts are readily accessible, and we do without the eccentric, which is usually the most troublesome part of a high speed engine

Lubrication.—The lubrication of the engine has been carefully worked out, and the most approved oil and grease cups are furnished.

Oil Guards.—Efficient oil guards are furnished and means provided to catch the drip from bearings so that the engine may easily be kept neat and clean.

The Governor.—The Rites Governor is used on all Liddell Engines, and is now so universally used by the better class of engine builders, that it hardly needs more than a passing comment. It will be sufficient to say that the whole governor consists of but a single moving piece, swinging about a common supporting pin, without links, dashpots, or interlocking mechanisms, thus placing it on a plane of simplicity never before reached in the art; while the performance of the governor compares with its simplicity, since results are obtained with ease that have not hitherto been realized.

Connecting Rod.—The connecting rod is of forged steel, with adjustable boxes, lined with extra hard babbitt. The crank end has a strap securely held by fitted bolts; the cross head end is mortised out of the solid to receive the boxes. The wedges on both ends of connecting rod take up wear in the same direction, so that the length of the rod remains practically constant.

Cross Head.—The cross head is of the box type made light and strong, the pin is in the middle of the length so that the thrust, due to the angularity of the connecting rod, is distributed evenly over the whole surface of the gibbs. The gibbs are lined with genuine babbitt and are turned to fit the

Liddell Automatic Engines, Continued.

guides. Adjustment for wear is provided, but the wearing surface is so large and the means of lubrication so perfect that the actual wear after years of service is hardly perceptible. The cross head pin is of steel, ground perfectly true, and can be turned one-quarter round to prevent wearing flat. It is held in position by key and bolt.

Crank Shaft.—The crank shaft is an open-hearth steel forging all in one piece, with crank pin larger than the rest of the shaft, to insure the greatest stiffness. The crank pin and main bearings are ground perfectly round and smooth. Cast iron counterbalance discs of sufficient weight to properly balance the engine are securely keyed to the shaft and turned and polished.

Cylinder.—The cylinder is made of a special mixture of strong, close-grained iron, which takes a high polish. On account of the light piston that we use there is very little danger of cutting. The cylinder heads have ground joints and the valve seat is scraped to a surface plate. The cylinder is neatly jacketed and packed with mineral wool to prevent radiation.

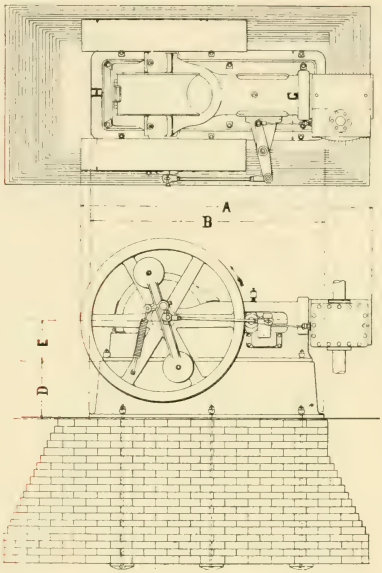
Wheels.—The wheels are made sufficiently heavy to insure steady running under ordinary conditions of service. When engines are to be used for electric railroad, or other work where the load fluctuates greatly, we make the wheels extra heavy. The wheels are turned perfectly true, balanced and keyed to shaft.

Frame.—The frame is of pleasing form, with plenty of metal properly distributed to resist and absorb the working strains. The guides are bored out, and the head of frame bored and faced to receive cylinder at the same chucking, so that they must be in perfect alignment. The pillow blocks are also bored out to receive cast iron shells, lined with genuine babbitt metal. The shells can be re-babbitted or new ones inserted at any time, and the correct alignment of the engine maintained.

Cast-Iron Sub-Base.—The cast-iron sub-base (which is extra) is high enough to swing the wheels clear of the floor, and takes the place of the usual capstone. It reduces the cost of foundation and adds to the appearance of the Engine.

Note.—This engine is not yet built for direct connection to generators.

Liddell Automatic Engines, Continued.



Sectional Diagram and Floor Plan.

Table of Principal Dimensions High Pressure Engines.

(In Feet and Inches.)

Size Engine.	A	B	D	E	G	H	Brick Foundation. (Over all Dimensions.) Length.	Width.	Depth.
6½ x 8	5-9¼	4-7½	1-3	10	1-11	3-1	8-1	3-10	3-6
7½ x 8	5-9¼	4-7½	1-3	10	1-11	3-1	8-1	3-10	3-6
8½ x 9	6-3¾	5-1	1-3	11	2-1⅛	3-3¾	8-6	4-3	3-6
9½ x 10	7-0	5-7¼	1-4	1-0	2-3⅝	3-8	9-0	4-6	3-6
10½ x 12	8-2	6-4	1-6½	1-1½	2-6	4-3½	10-0	5-0	3-6
12 x 12	8-4½	6-7½	1-9	1-3	2-11⅛	4-10½	10-3	5-3	4-0
13 x 12	8-4½	6-7½	1-9	1-3	2-11⅛	4-10½	10-3	5-3	4-0
14 x 14	9-7⅝	7-8	1-10	1-4	3-3½	5-8	12-0	6-0	4-6
16 x 14	9-8⅛	7-8	1-10	1-4	3-3½	5-10	12-0	6-0	4-6

Liddell Automatic Engines, Concluded.

Table of Horse Power, Speed and General Data.

Cylinder.		Rev. per Minute.	I. H. P. at ¼ cut-off. Lbs. Initial Pressure.			Fly Wheel.		Diam. of Pipes.	
Diam. Inches.	Stroke Inches.		60	80	100	120	Diam. Inches.	Face Inches.	Steam Inches	Exhaust Inches.
6½	8	300	12.0	16.0	20.1	24.1	36	7½	2	3
		325	13.0	17.4	21.7	26.1				
		350	14.0	18.7	23.4	28.0				
7½	8	300	16.0	21.4	26.7	32.1	36	7½	2	3
		325	17.4	23.2	29.0	34.8				
		350	18.7	25.0	31.2	37.5				
8½	9	300	23.2	30.9	38.7	46.4	40	8	2½	3
		325	25.1	33.5	41.9	50.3				
		350	27.0	36.0	45.0	54.0				
9½	10	275	29.5	39.3	49.2	59.0	45	9	2½	3½
		300	32.2	42.9	53.7	64.4				
		325	34.9	46.5	58.2	69.8				
10½	12	250	39.3	52.5	65.6	78.7	54	11	3	4
		275	43.3	57.7	72.1	86.6				
		300	47.2	63.0	78.7	94.4				
12	12	250	51.4	68.5	85.7	102.9	56	13	4	5
		275	56.5	75.4	94.2	113.1				
		300	61.7	82.2	102.8	123.4				
13	12	250	66.3	86.4	100.5	120.6	56	13	4	5
		275	66.4	88.5	110.6	132.7				
		300	72.4	96.5	120.7	144.8				
11	14	225	73.5	97.8	122.5	146.8	63	14	4	6
		240	78.4	104.5	130.6	156.6				
		260	85.2	113.2	141.5	169.8				
		275	89.8	119.7	149.6	179.6				
16	14	225	95.9	127.8	159.8	191.8	64	16	5	7
		240	102.2	136.5	170.6	204.6				
		260	110.8	147.9	184.8	221.7				
		275	117.1	156.3	195.5	234.5				

Note.—The speeds shown in black type are those at which the engines will be set unless otherwise agreed.

TRAVELLING CRANES FOR ENGINE ROOMS.

For large power plants, a travelling crane in the engine room has become recognized as a necessity. Parts of machines can be handled and transported quickly with but very little labor

These cranes are divided into three types, depending upon whether they are driven by electricity, compressed air, or hand power. We illustrate the electric power crane as well as the hand power. At the same time, the hand power is considerably less expensive than either of the other types, and is all that is required for any power plant except very large central stations.

Whiting Hand-Power Travelling Cranes.

In these cranes all movements are operated by hand power by means of pendant hand chains. While not so convenient and possibly not so quick as the electric crane, the hand power type possesses one very important advantage, and that is it is always ready for use regardless of the operation of the power plant.

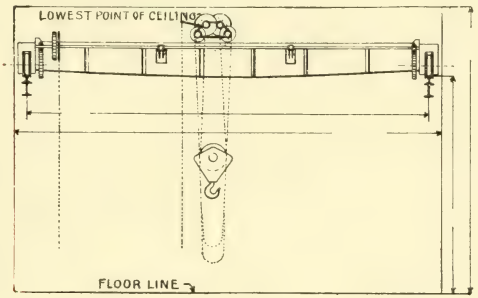
The span across the power house upon which the trolley travels, or the "bridge," as it is termed, is composed of two I beams, or built up girders, rigidly connected at the ends. The bridge travel gearing consists of a set of spur gears on each truck connected by the squaring-shaft running length of the bridge to move each end of the bridge squarely on runways at equal speed. It is operated by pendant hand chain.

The trucks consist of cast iron truck brackets and separator, attached to bridge, and contain bearings for main axles, carrying double flanged bridge wheels with treads all ground to uniform diameter.

The runways, or track upon which the crane travels, may be purchased with the crane or not, as desired. These runways ordinarily extend the full length of the engine room on each side. They may, however, of course, be shorter, simply enabling the trolley to cover a particular part of the engine room. Each runway consists of an I-beam of the proper depth and weight to give the required support, surmounted by a heavy T-rail for the track, together with the necessary anchor bolts, fish plates and bolts, rail clips and bolts, and pilaster caps.

Travelling Cranes, Continued.

The trolley has substantial frame fitted with chilled wheels, steel axles, and anti-friction roller bearings. It is of the free trolley type, with chain sprocket hoist. The trolley travel gearing consists of a train of spur gears located near end of the bridge and connected with trolley by sprocket chain. It is operated by pendant hand chain.



TRAVELING CRANE, CHAIN SPROCKET HOIST.

(Hand Power.)

The hoisting gearing consists of a train of spur gears driving a sprocket wheel operated from floor by pendant and chains. Two speeds are provided; each speed is operated by a separate chain. Back gearing is cut out, and power required greatly reduced when used for light loads or overhauling the empty hook. A brake of improved type automatically sustains the load and permits rapid lowering under perfect control. A great saving in time is effected over an ordinary chain block by this device and fast speed hoisting arrangement as well. The block is of an improved swivel pattern, carrying a heavy forged hook designed both to swing and turn. The sheaves are of ample diameter, and fitted with anti-friction roller bearings, rotating on steel shaft.

Guides are provided for all hand chains. Ample provision is made for lubrication.

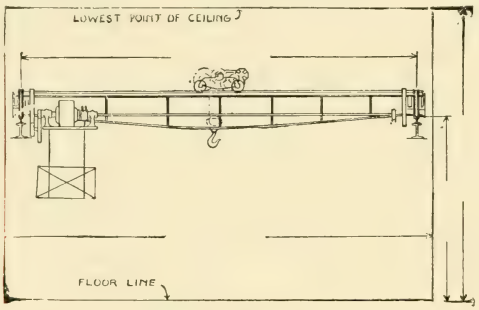
These cranes are made of any capacity desired. In selecting the proper size crane, it is of course necessary to notify the builder of the weight of the heaviest piece that it will be called upon to handle.

The crane is put together at the works, painted and

Travelling Cranes, Concluded.

finished in a workmanlike manner, and marked for re-assembling, being taken apart only sufficiently for proper handling, boxing, and shipment.

The crane includes the bridge fitted with trucks, wheels and bridge travel gearing, complete trolley and hoisting gearing, hook and block, and the necessary hoisting chain: in short, complete ready to set on runways.



TRAVELING CRANE.

The above crane is motor driven and suitable only for any large central stations.

The following dimensions and data are required by the builder for making an estimate upon this class of work:

Indicate dimensions left blank on the above diagrams of Crane or Cranes, and give following data:

Capacity required (heaviest load)_____

Character of Service (occasional lifting or constant service)_____

Special features required, Power preferred_____

If power Crane, give speeds desired for different movements_____

For travelling Cranes give length of track in feet. If runways are required give spacing for track supports in feet.

MODERN INSTALLATIONS OF PIPING.

(Embracing Bent Steel Elbows, Bent Piping where Necessary, High Pressure Steam Gate Valves, Pipe Covering, etc.)

Until the introduction of high pressures, ordinary cast iron screwed pipe fittings, the ordinary types of valves, and light weight piping, thrown together by indifferent mechanics, after all manner of designs—good, bad and indifferent—constituted a more or less satisfactory outfit to the purchaser. With the introduction of high pressures, however, all this was changed, and a modern high pressure steam piping job requires not only good materials and good design, but skillful steam fitters. Pipe fitting, valves, and all the accessories should be tested for a working pressure of 200 lbs. to the square inch.

Expansion joints of the old slip type have entirely disappeared; allowance for contraction and expansion is provided by long bends, or by providing a double swing in laying out the piping (something like a gas bracket, on which the fittings turn on the threads of the nipple). Screwed fittings and valves have been superseded by flanged fittings and valves, and by agreement among the different makers all valves and fittings of both light and heavy weight are uniform, not only in dimensions but also in size and number of bolts, diameter of bolt circles, etc.

Valves in particular have been greatly improved, gate valves being almost exclusively used for high pressure work. The best type of gate valve is that with yoke and outside screw. For very large valves in electric power stations they are often operated by small motors,—which not only makes an easy method of operating the valve but a quick opening and shutting of it. For the larger sizes these valves should be fitted with small gate valves in-pass. Incidentally, valves should be opened and closed often enough to keep them in good order, and they will then remain tight for many years.

High pressures have introduced two new dangers into power plants. In the first place, the rupture of a pipe or fitting, or other accident flooding the room with steam, makes it impossible to shut off a valve by hand. In the second place, firing up a cold boiler and opening the steam valves before the pressure in it has reached that of the other

Modern Piping Installations, Continued.

boilers, has always been a source of danger, causing many disastrous explosions ; this is more liable to occur with high pressure work than ever before. The Foster Non-Return Automatic Emergency Valve has been designed to overcome this. It not only automatically acts in emergencies, but can be controlled from a distant point. It can also of course be operated in the usual manner by hand. These valves add somewhat to the cost of the piping of a power plant, but the amount of money invested in a modern steam plant is too great to be penny-wise at this important stage.

Extra heavy fittings should be used on gauges, lubricators and high pressure drip connections.

Ample disposition should be made for the water of condensation,—either removing it by trapping it to the hot well, or returning it to the boiler by automatic pump and receiver, or by the Holly Gravity Return System.

It is of course quite out of the question to give any fixed rules for laying out steam piping; experience in designing and installing high pressure work is the only safe and reliable guide. Generally, however, as unnecessary as it may seem to remark upon it, too much emphasis can not be laid upon making all steam lines as straight and with as few changes of direction as possible. This item becomes of peculiar significance and importance when it relates to superheated steam.

During the past few years it has been quite a fad among certain engineers and engine builders to exaggerate the desirability of piping engines beneath the floor, thereby doing away with all steam piping in the engine room. It is a decidedly attractive proposition and for low and medium pressures makes a satisfactory enough job.

On the other hand, however, with the introduction of pressures of 150 pounds and upwards, and particularly in connection with superheat, as mentioned above, this design is not only faulty but radically wrong, extravagant and wasteful. After leaving the steam drum, the piping to the engine should be taken straight through the division wall between the engine and boiler rooms and dropped right into the throttle valve on top of the high pressure cylinder through a section of bent pipe of not less than average radius.

After the steam leaves the high pressure cylinder, however, all the other piping and valves can well be placed

Modern Piping Installations, Continued.

beneath the floor of the engine room and operated with extended stems by hand wheels and floor stands.

For very large engines, some engineers recommend a receiver or separator just above the throttle on the high pressure cylinder for providing a uniform flow of steam. This is a refinement that undoubtedly possesses merit, but is particularly valuable with long runs of steam piping. Where the distances are short, it may be dispensed with.

It has become common practice in the South to require special piping so that either cylinder may be independently run high pressure. This is an unnecessary complication, and is providing for a contingency that is exceedingly unlikely to arise. It of course can be done, but it involves a considerable additional outlay, and in numbers of cases the valves are unused for such a long period of time that when it is desired to use them, they are found stuck and otherwise unserviceable. The trend of modern piping is toward simplicity, and this is a questionable precaution In fact, it may be more properly termed an excess of caution. At the same time, I have thought it best to show such an arrangement for piping the cylinders independently as contrasted with the usual method. Of course, both of these diagrams show only sample arrangements, as numbers of different lay outs (all probably equally good) would accomplish the same result.

Wrought Iron and Steel Pipe Bends.

The advantages derived from such bends are, briefly:

1st. They are 100 per cent. stronger than cast iron fittings.

2d. There is little reduction of pressure between boilers and engines on account of friction, as the steam travels as easily through an average radius bend as through a straight pipe.

3d. By reducing the friction they increase the efficiency of the plant, and therefore reduce the coal bills.

4th. They reduce to a minimum the number of flanged or screwed joints, which are always a source of trouble.

5th. By proper arrangement they can be made to take care of the expansion and contraction of a whole system of piping without the use of such expensive and troublesome devices as expansion joints.

The following table shows the minimum and average radii to which standard pipes can be bent. Only where necessary

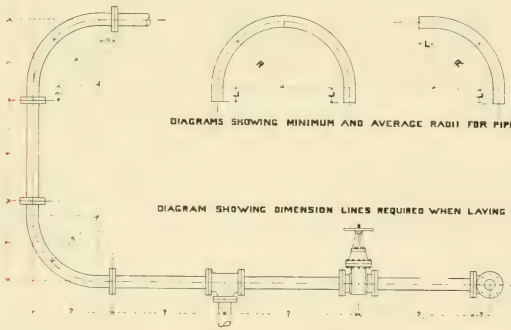
Modern Piping Installations, Continued.

use the minimum radius given; try to use not less than the average.

One can always bend to a greater radius than given.

Extra heavy pipe can be bent to a shorter radius than standard pipe, but the bends are stiffer.

180° or U Bends cannot be made of pipe above 12″ diameter, as the average length of pipe does not exceed twenty (20) feet.

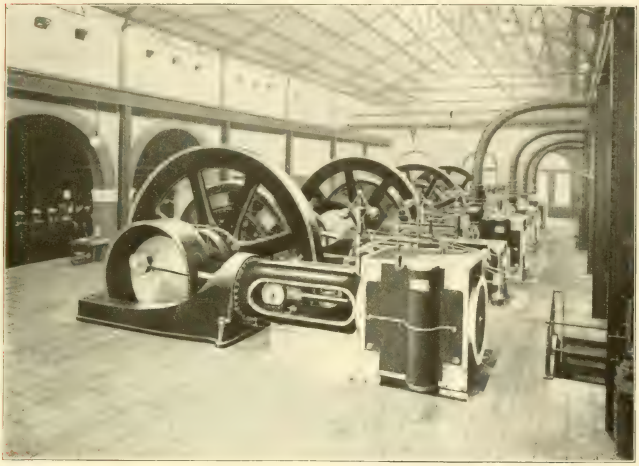


DIAGRAMS SHOWING MINIMUM AND AVERAGE RADII FOR PIPE BENDS.

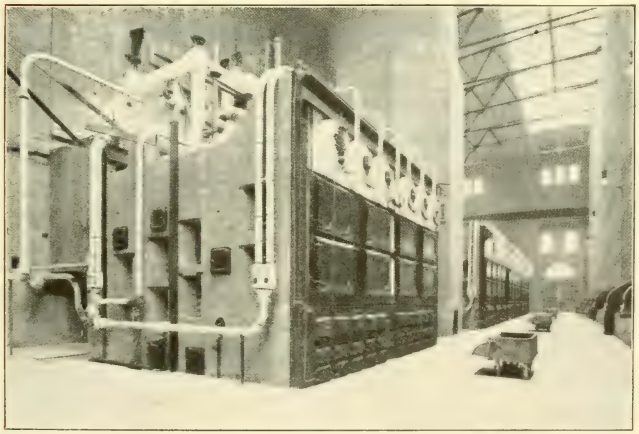
DIAGRAM SHOWING DIMENSION LINES REQUIRED WHEN LAYING OUT PIPING.

Inside Diameter of Pipe.	Minimum Radius. R	Average Radius. R	Length. L	Outside Diameter of Pipe.	Minimum Radius. R	Average Radius. R	Length L
2	4½	8	3	14	7-0	7-6	12
2½	6	9	4	15	7-0	7-6	12
3	8	12	4	16	7-6	8-0	12
3½	10	14	5	18	8-6	9-6	18
4	14	18	5	20	9-6	10-0	18
4½	16	20	6	22	10-6	11-0	18
5	20	2- 3	6	24	11-6	12-0	18
6	2- 0	2- 9	8				
7	3- 0	3- 4	8				
8	3- 4	3- 6	8				
9	4- 0	4- 2	9				
10	4- 4	4- 8	10				
12	5- 6	6- 0	12				

Modern Piping Installations, Continued.

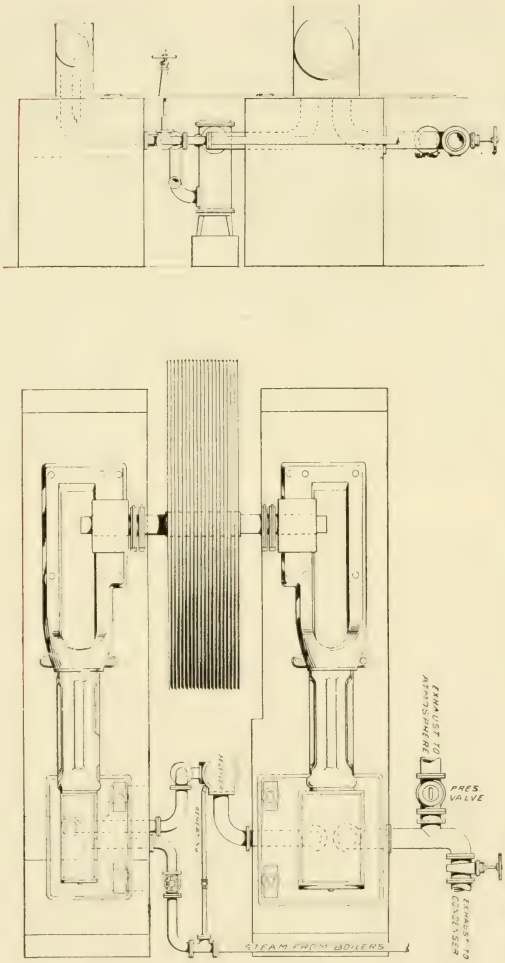


A Model Engine Room.



A Model Boiler Room.

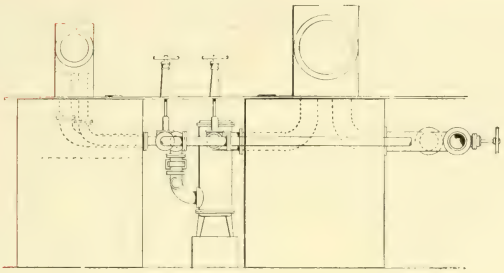
Modern Piping Installations, Continued.

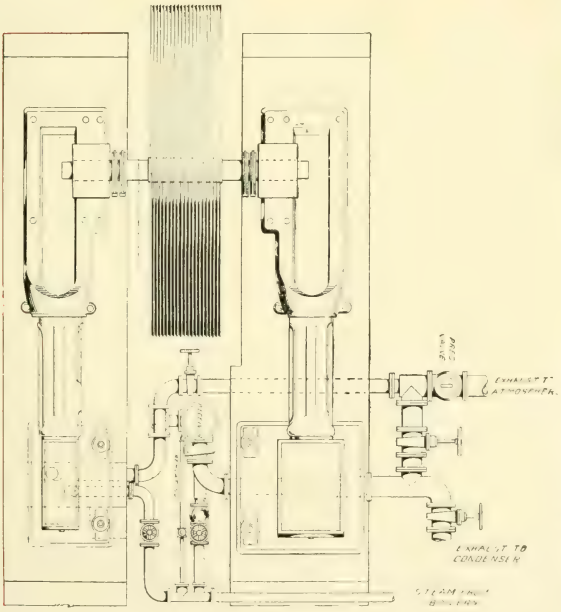


Showing sample arrangement of piping for taking steam underneath the floor, in the usual manner.

Diagrams for
Cross Compound Condensing Engine.

Modern Piping Installations, Continued.





Showing sample arrangement of piping for taking steam underneath the floor, and also for running either side high pressure, condensing or non-condensing.

Diagrams for
Cross Compound Condensing Engine.

Modern Piping Installations, Continued.

Steam Pipe Covering.

The value of steam pipe covering is too generally known to require any argument in favor of it. The following, however, will be found interesting:

Mr. H. G. Stott made a series of tests before awarding the contract for covering the steam pipes in the Manhattan Railway Company's power house in New York. His investigation included tests not only of different types but different thicknesses of covering.

The following table shows the results of the test for different classes of covering:

Electrical Test of Steam Pipe Covering.

No. of Curve.	COVERING.	Aver. Thickness.	* B. T. U. Loss Per Sq. Ft at 100 Lb. Pr.	% Heat Saved by Covering.
2	Solid Cork Sectional	1.68	1,002	87.1
3	85% Magnesia "	1 18	2,008	84.5
4	Solid Cork "	1.20	2,048	84.2
5	85% Magnesia "	1.19	2,130	83.0
6	Laminated Asbesto Cork "	1.48	2,123	83.7
7	85% Magnesia "	1.12	2,190	83.2
8	Asbestos Air Cell [Indent] " [Imperial]	1.26	2,333	83.1
9	Asbestos Sponge Felted "	1.24	2 552	80.3
10	Asbestos Air Cell [Long] "	1.70	2,750	78.8
11	"Asbestocel" [Radial] "	1.22	2,801	78.5
12	Asbestos Air Cell [Long] "	1.29	2,812	78.4
13	"Standard" Asbestos "	1.12		
14	"Magnesian" "	1.28		
15	"Remanit" [Silk] Wrapped	1.51	1,452	88 8
16	85% Magnesia 2" Sectional and ½" Block	2.71	1,381	89 4
17	" " " " " ½" Plaster	2 45	1,387	88 7
18	" " 2 1" "	2.50	1,412	89.0
19	" " 2-1" "	2.24	1,465	88.7
20	" " 2" "	2.34	1,555	88.0
21	" " 2" "	2.20	1,568	87 9
	Bare Pipe [From Outside Tests]		13,000	

* Net loss is expressed in B. T. U. per square foot of pipe surface per minute.

The deductions made from these and other tests are interesting. The most important one is that there seems to be no reason for the former practice of putting on different thicknesses of covering on different sizes of pipes, except for the mechanical difficulty of applying a very heavy covering to a small pipe. This difficulty can be overcome by putting the covering on in two separate layers.

Modern Piping Installations, Continued.

Recording Pressure Gauges and Regulating Devices for Maintaining Constant Steam Pressures.

Briefly stated, a uniform steam pressure means a better engine performance and a corresponding saving in coal, not to mention a greater length of life to grates and to the boilers generally.

Recording Pressure Gauges.

A recording pressure gauge enables the management of a mill, with but a moment's inspection, just as carefully to check up the carefulness and fidelity of his fireman as the rounds of his night watchman by the readings of his time detector.

Locke's Graduated Hydraulic Damper Regulator.

This type of regulator is generally placed in the engine room and is used with either brick or iron stacks in connection with natural draft. With patent cut-off attachment the damper is maintained in a partially open condition and never allowed to go fully open or closed except in cases of necessity. It holds the damper at partial stroke, steadily and securely, the regulator having water both above and below the diaphragm. The water valve has changeable seat rings. The spindle and rings are made of composition nickel.

The regulator is a cold water machine, taking water from city water supply or from the mill tank. The water is admitted through a small valve attached to and operated by the lever of the steam weighing device, which vibrates with every pulsation of steam ; whenever the steam pressure varies a fraction of a pound, the beam moves correspondingly to open a passage for water to the damper motor, which in turn moves the damper by chains or wires just enough to change the draft to bring the steam pressure to normal again.

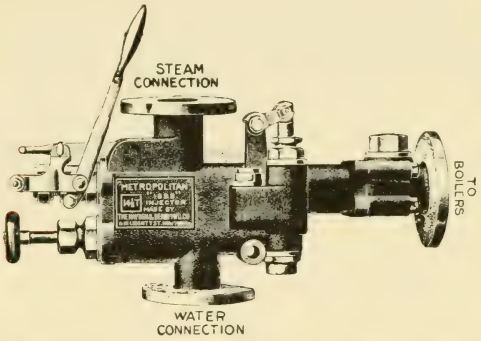
Steam Pressure Regulating Valve.

This type of regulator is specially designed for and used in connection with mechanical draft. As the steam pressure varies, the regulating valve automatically controls the supply to the fan engine, increasing or diminishing their speed, and thus effecting the change in the draft required to bring the steam pressure to normal again.

Modern Piping Installations, Continued.

Injectors.

There are two types of injectors: the automatic or open overflow, and the double tube or closed overflow.



Metropolitan "1898" Double Tube, Model T Injector.

It is poor policy to have an injector work at its highest limit, for as soon as it begins to wear the range is decreased. The double tube injector is the type most largely used. For high steam pressure and hot feed water, a special type of injector is recommended, including detachable vertical check valve, known as "1898" Model T.

The capacity of an injector is always decreased as the lift is increased or the feed water heated. Also if the feed water is heated, a greater steam pressure is required to start the injector and it will not work with as high steam pressure.

Table of Standard Sizes.

Sizes in Inches.	Size of all Pipe Connections in Inches.	Size Overflow or Waste Pipe in Inches.	Capacity per Hour with 100 lbs. Steam Pressure.	Capacity per Hour with 175 lbs. Steam Pressure.	Horse Power on a Basis of 30 lbs. Evaporation per H. P per Hour.
11½	1½	1¼	1350 gals.	1550 gals.	180 to 235
12½	1½	1¼	1800 gals.	2070 gals.	235 to 300
13½	2	1½	2350 gals.	2675 gals.	300 to 400
14½	2	1½	2900 gals.	3275 gals.	400 to 500
15½	2½	2	3600 gals.	3975 gals.	500 to 650
16½	2½	2	4300 gals.	4750 gals.	650 to 800

Modern Piping Installations, Concluded.

The Steam Range of the Metropolitan "1898" Injector.

The great range of the Metropolitan "1898" Injector is shown by the data given below, and it will be apparent that this injector is suitable for all ordinary conditions found in practice.

With Cold Feed Water.

On a 2-foot lift	Starts with 25 pounds steam pressure. Works up to 300 pounds steam pressure.
On an 8-foot lift	Starts with 35 pounds steam pressure. Works up to 270 pounds steam pressure.
On a 14-foot lift	Starts with 45 pounds steam pressure. Works up to 240 pounds steam pressure.
On a 20-foot lift	Starts with 65 pounds steam pressure. Works up to 185 pounds steam pressure.
When not lifting	Starts with 25 pounds steam pressure. Works up to 300 pounds steam pressure.

With Feed Water at 100° Fahr.

On a 2-foot lift	Starts with 30 pounds steam pressure. Works up to 265 pounds steam pressure.
On an 8-foot lift	Starts with 40 pounds steam pressure. Works up to 235 pounds steam pressure.
On a 14-foot lift	Starts with 50 pounds steam pressure. Works up to 210 pounds steam pressure.
On a 20-foot lift	Starts with 70 pounds steam pressure. Works up to 155 pounds steam pressure.
When not lifting	Starts with 25 pounds steam pressure. Works up to 265 pounds steam pressure.

With Feed Water at 120° Fahr.

On a 2-foot lift	Starts with 35 pounds steam pressure. Works up to 230 pounds steam pressure.
On an 8-foot lift	Starts with 45 pounds steam pressure. Works up to 205 pounds steam pressure.
On a 14-foot lift	Starts with 55 pounds steam pressure. Works up to 140 pounds steam pressure.
On a 16-foot lift	Starts with 65 pounds steam pressure. Works up to 120 pounds steam pressure.
When not lifting	Starts with 35 pounds steam pressure. Works up to 230 pounds steam pressure.

With Feed Water at 140° Fahr.

On a short lift, or when not lifting, this injector will work with steam pressures from 35 to 140 pounds, and on an 8-foot lift with steam pressures from 45 to 110 pounds.

Under favorable conditions this Injector will take feed water up to 150° Fahr.

DATA RELATING TO PIPING.

Flow of Steam Through Pipes.

(Babcock and Wilcox.)

The approximate weight of any fluid which will flow in one minute through any given pipe with a given head or pressure may be found by the following formula :

$$W = 87 \sqrt{\frac{D(p_1 - p_2)d^5}{L\left(1 + \frac{3.6}{d}\right)}}$$

in which W=weight in pounds avoirdupois, d=diameter in inches, D=density or weight per cubic foot, p_1=the initial pressure, p_2=pressure at end of pipe, and L=the length in feet.

The table on the following page gives, approximately, the weight of steam per minute which will flow from various initial pressures, with one pound loss of pressure through straight smooth pipes, each having a length of 240 times its own diameter.

For sizes of pipe below six inch, the flow is calculated from the actual areas of "standard" pipe of such nominal diameters.

For horse-power, multiply the figures in the table by 2. For any other loss of pressure, multiply by the square root of the given loss. For any other length of pipe, divide 240 by the given length expressed in diameters, and multiply the figures in the table by the square root of this quotient, which will give the flow for 1 lb. loss of pressure. Conversely, dividing the given length by 240 will give the loss of pressure for the flow given in the table.

The loss of head due to getting up the velocity, to the friction of the steam entering the pipe, and passing elbows and valves, will reduce the flow given in the tables. The resistance at the opening, and that at a globe valve, are each about the same as that for a length of pipe equal to 114 diameters divided by a number represented by 1 + (3.6 ÷ diameter). For the sizes of pipes given in the table, these corresponding lengths are :

SIZES OF PIPE IN INCHES.												
¾	1	1¼	2	2½	3	4	5	6	8	10	12	15	18
20	25	34	41	47	52	60	66	71	79	84	88	92	95

Table of Flow of Steam Through Pipes.

Initial Pressure by Gauge. Pounds per Square Inch.	Diameter of Pipe in Inches. Length of Each=240 Diameters.													
	¾	1	1½	2	2½	3	4	5	6	8	10	12	15	18
	Weight of Steam per Minute, in Pounds, with One Pound Loss of Pressure.													
1	1.16	2.07	5.7	10.27	15.45	25.38	46.85	77.3	115.9	211.4	341.1	502.4	804	1177
10	1.44	2.57	7.1	12.72	19.15	31.45	58.05	95.8	143.6	262.0	422.7	622.5	996	1458
20	1.70	3.02	8.3	14.94	22.49	36.94	68.20	112.6	168.7	307.8	496.5	731.3	1170	1713
30	1.91	3.40	9.4	16.84	25.35	41.63	76.84	126.9	190.1	346.8	559.5	824 1	1318	1930
40	2.10	3.74	10.3	18.51	27.87	45.77	84.49	139.5	209.0	381.3	615.3	906.0	1450	2122
50	2.27	4.04	11.2	20.01	30.13	49.48	91.34	150.8	226.0	412.2	665.0	979.5	1567	2294
60	2.43	4.32	11.9	21.38	32.19	52.87	97.60	161.1	241.5	440.5	710.6	1046.7	1675	2451
70	2.57	4.58	12.6	22.65	34.10	56.00	103.37	170.7	255.8	466.5	752.7	1108.5	1774	2596
80	2.71	4.82	13.3	23.82	35.87	58.91	108.74	179.5	269.0	490.7	791.7	1166.1	1866	2731
90	2.83	5.04	13.9	24.92	37.52	61.62	113.74	187.8	281.4	513.3	828.1	1219.8	1951	2856
100	2.95	5.25	14.5	25.96	39.07	64.18	118.47	195.6	293.1	534.6	862.6	1270.1	2032	2975
120	3.16	5.63	15.5	27.85	41.93	68.87	127.12	209.9	314.5	573.7	925.6	1363.3	2181	3193
150	3.45	6.14	17.0	30.37	45.72	75.09	138.61	228.8	343.0	625.5	1009.2	1486.5	2378	3481

The resistance at an elbow is equal to two-thirds that of a globe valve. These equivalents—for opening, for elbows, and for valves—must be added in each instance to the actual length of pipe. Thus a 4 inch pipe, 120 diameter (40 feet) long, with a globe valve and three elbows, would be equivalent to 120 + 60 + 60 + (3x40) = 360 diameters long; and 360 ÷ 240 = 1½. It would therefore have 1½ lbs. loss of pressure at the flow given in the table, or deliver (1 ÷ 1 1½ = .816) 81 6 per cent. of the steam with the same (1 lb.) loss of pressure.

Data Relating to Piping, Continued.

Table of Standard Dimensions of Standard Wrought-Iron Welded Pipe.

Diameter.			Thickness.	Circumference.	Transverse Areas	Length of Pipe per Sq. Foot of	Length of Pipe Containing One Cubic Foot.	Nominal Weight per Foot.	Number of Threads per Inch of Screw.
Nominal Internal.	Actual External.	Actual Internal.		External.	Internal.	External Surface.			
Inches.	Inches.	Inches.	Inches.	Inches.	Sq. Inches.	Feet.	Feet.	Pounds.	
⅛	.405	.27	.068	1.272	.0573	9.44	2513.	.241	27
¼	.54	.364	.088	1.696	.1041	7.075	1383.3	.42	18
⅜	.675	.494	.091	2.121	.1917	5.657	751.2	.559	18
½	.84	.623	.109	2.639	.3048	4.547	472.4	.837	14
¾	1.05	.824	.113	3.299	.5333	3.637	270.	1.115	14
1	1.315	1.048	.134	4.131	.8626	2.904	166.9	1.668	11½
1¼	1.66	1.38	.14	5.215	1.496	2.301	96.25	2.244	11½
1½	1.9	1.611	.145	5.969	2.038	2.01	70.66	2.678	11½
2	2.375	2.067	.154	7.461	3.356	1.608	42.91	3.609	11½
2½	2.875	2.468	.204	9.032	4.784	1.328	30.1	5.739	8
3	3.5	3.067	.217	10.996	7.388	1.091	19.5	7.536	8
3½	4.	3.548	226	12.566	9.887	.955	14.57	9.001	8
4	4.5	4.026	.237	14.137	12.73	.849	11.31	10.665	8
4½	5.	4.508	.246	15.708	15.961	.764	9.02	12.34	8
5	5.563	5.045	.259	17.477	19.99	.687	7.2	14.502	8
6	6.625	6.065	.28	20.813	28.888	.577	4.98	18.762	8
7	7.625	7.023	.301	23.955	38.738	.501	3.72	23.271	8
8	8.625	7.982	.322	27.096	50.04	.443	2.88	28.177	8
9	9.625	8.937	.344	30.238	62.73	.397	2.29	33.701	8
10	10.75	10.019	.366	33.772	78.839	.355	1.82	40.665	8
11	12.	11.25	.375	37.699	99.402	.318	1.456	45.95	8
12	12.75	12.	.375	40.055	113.098	.299	1.27	48.985	8
13	14.	13.25	.375	43.982	137.887	.273	1.04	53.921	8
14	15.	14.25	.375	47.124	159.485	.255	.903	57.893	8
15	16.	15.25	.375	50.265	182.655	.239	.788	61.77	8

Data Relating to Piping, Continued.

Table of Standard Dimensions, Wrought-Iron Welded Pipe, Concluded.

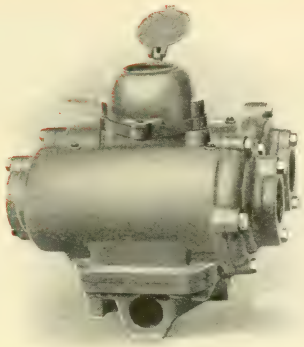
	Diameter.			Thickness.	Nearest Wire Gauge	Circumference.	Transverse Areas.	Length of Pipe per Sq. Foot of External Surface.	Nominal Weight per Foot.
	Nominal Internal.	Actual External.	Actual Internal.			External.	Internal.		
	Inches.	Inches.	Inches.	Inches.	No.	Inches.	Sq. Inches.	Feet.	Pounds.
Extra Strong.	⅛	.405	.205	.1	12½	1.272	.033	9.433	.29
	¼	.54	.294	.123	11	1.696	.068	7.075	.54
	⅜	.675	.421	.127	10½	2.121	.139	5.657	.74
	½	.84	.542	.149	9	2.639	.231	4.547	1.09
	¾	1.05	.736	.157	8½	3.299	.452	3.637	1.39
	1	1.315	.951	.182	7	4.131	.71	2.904	2.17
	1¼	1.66	1.272	.194	6½	5.215	1.271	2.301	3.
	1½	1.9	1.494	.203	6	5.969	1.753	2.01	3.63
	2	2.375	1.933	.221	5	7.461	2.935	1.608	5.02
	2½	2.875	2.315	.28	2	9.032	4.209	1.328	7.67
	3	3.5	2.892	.304	1	10.996	6.569	1.091	10.25
	3½	4.	3.358	.321	0	12.566	8.856	.955	12.47
	4	4.5	3.818	.341	0	14.137	11.449	.849	14.97
	5	5.563	4.813	.375	00	17.477	18.193	.687	20.54
	6	6.625	5.75	.437	000	20.813	25.967	.577	28.58
Double Extra Strong.	½	.84	.244	.298	1	2.639	.047	4.547	1.7
	¾	1.05	.422	.314	1	3.299	.139	3.637	2.44
	1	1.315	.587	.364	00	4.131	.271	2.904	3.65
	1¼	1.66	.885	.388	00	5.215	.615	2.304	5.2
	1½	1.9	1.088	.406	000	5.969	.93	2.01	6.4
	2	2.375	1.491	.442	0000	7.461	1.744	1.608	9.02
	2½	2.875	1.755	.560	1/16—	9.032	2.419	1.328	13.68
	3	3.5	2.284	.608	3/8—	10.996	4.097	1.091	18.56
	3½	4.	2.716	.642	5/8+	12.566	5.794	.955	22.75
	4	4.5	3.136	.682	1/16	14.137	7.724	.849	27.48
	5	5.563	4.063	.75	1/4	17.477	12.965	.687	38.12
	6	6.625	4.875	.875	7/8	20.813	18.666	.577	53.11

Data Relating to Piping, Concluded.

Table of Dimensions of Cast-Iron Bell and Spigot Pipe for Water, Etc.

Inside Diam. of Pipe in Inches.	Approximate Laying Length in Feet.	Head, 100 Feet. Pressure, 43 Lbs.			Head, 200 Feet. Pressure, 86 Lbs.			Head, 300 Feet. Pressure, 130 Lbs.			Head, 400 Feet. Pressure, 173 Lbs.			Lead per Joint. Lbs.	Hemp per Joint, Lbs.
		Thick-ness.	Weight per		Thick-ness.	Weight per		Thick-ness.	Weight per		Thick-ness.	Weight per			
			Foot.	Lgth.		Foot.	Lgth.		Foot.	Lgth.		Foot.	Lgth.		
2	9	.27	6.7	60	.....	....	....	.....	.....	....	.....	.....	... ..	3.25	.14
2½	9	.27	8.0	72	.....	.....	....	.....	.....	...	.....	.....	.....	3.90	.16
3	12	.38	13.9	167	.42	15.4	185	.45	16.7	200	.45	16.7	200	4.4	.18
3½	12	.39	16.5	200	.42	13.0	215	.45	18.5	220	.46	20.0	240	5.0	.20
4	12	.40	19.2	230	.42	20 3	243	.45	21.7	260	.47	22.1	265	5.5	.21
5	12	.42	24.6	295	.45	26 3	315	.48	28.2	338	.51	29.6	355	6.8	.27
6	12	.43	30.4	364	.47	32.8	393	.51	35.5	426	.54	37.1	445	8.0	.31
7	12	.45	36.7	440	.49	40.0	480	.53	43.3	520	.58	46.3	555	9.8	.37
8	12	.47	42.8	513	.51	47.3	567	.56	52.0	624	.61	55.4	665	11.5	.44
9	12	.48	49.6	595	.54	55 8	670	.59	61 3	735	.64	65.0	780	13.0	.48
10	12	.50	57.1	685	.56	63.8	765	.62	71 0	852	.68	76.7	920	14.5	.53
12	12	.53	72.5	870	.60	82.1	985	.68	92.5	1110	.75	100.8	1210	18.0	.61
14	12	.56	89.5	1074	.65	102.4	1229	.73	116.6	1399	.82	128.3	1540	21.5	.81
15	12	.58	98.3	1180	.67	114.2	1370	.76	129.2	1550	.85	141.7	1700	23.0	.87
16	12	.60	107.8	1293	.69	124 7	1496	.79	143.6	1723	.89	158.3	1900	24.0	.94
18	12	.63	127.7	1532	.74	149.0	1788	.85	172.1	2065	.96	191.7	2300	27.0	1.00
20	12	.66	149.0	1788	.78	175.3	2104	.91	203.7	2444	1.03	228.3	2740	31.5	1.25
24	12	.75	200.6	2407	.87	233.6	2803	1.02	274 9	3299	1.16	306.7	3680	37.0	1.50
30	12	.87	290.2	3482	1 01	335.6	4027	1.19	398.6	4783	1.37	451.7	5420	51.0	2.06
36	12	.98	391 6	4099	1.14	455.0	5460	1 36	545.3	6543	1.58	624.2	7490	75.0	3.00
40	12	1.09	483.9	5807	1.23	543.8	6525	1.48	654.8	7858	1.72	754.2	9050	85.0	3.37
42	12	1.16	512 3	6147	1.28	591.7	7100	1.54	713.6	8563	1.79	824.2	9890	90.0	3.62
48	12	1.25	665.2	7982	1.41	745.5	8946	1.71	904.8	10857	1.99	1045.8	12550	110.0	4.37

In ordering Lead, add 20 per cent.



THE WORTHINGTON WATER METER.

Every engineer who has control of a boiler plant has felt the necessity of having some simple device by which the amount of water fed to the boilers could be accurately determined. With such an appliance at hand, and by weighing the coal consumed, it becomes an easy matter to keep a record of the amount of water evaporated per pound of coal.

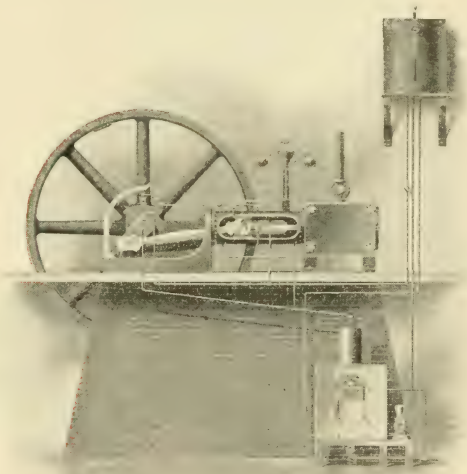
Owing to the error introduced by dealing with very hot water under high pressures, the amount registered by the meter may not be exactly the same as that passing through the meter; but the difference between the two readings is always constant, and, when determined and applied to the previous reading, the actual amount passing through the meter will be given. A special arrangement of cocks and pipes, including thermometer, constituting a by-pass, can be furnished with the meter when desired, by which this difference can be obtained.

The different sizes are as follows:

Size of Pipe Opening. In Inches.	Greatest Proper Quantity per Minute.	
	Cubic Feet.	Gallons.
⅝	1½	11¼
¾	3	22½
1	5	37½
1½	6	45
2	8	60
3	23	172
4	58	435
6	120	900

GRAVITY OILING SYSTEMS.

A complete pipe system of oiling dispenses with eighty per cent. of the labor and attention by automatically handling all the oil applied to or released from the machinery ; it also reduces to a minimum friction and its attendant expense for repairs by continually supplying the bearings with an abundance of oil.



One of the best of the types is the White Star Duplex Oil Filter, piped up complete, with pump and reservoir, as illustrated in the above cut. The oil is fed to the self-oiling cups by gravity from the elevated reservoir, and after passing through the bearings, is carried off in piping to the filter, where it is purified and returned by the pump to the storage tank above. A third pipe carries any surplus back to the filter from the reservoir and prevents overflow. The supply of oil is thus continuous and uniform.

In some systems the reservoir is dispensed with, and instead of the oil being fed by gravity, the pump forces it directly to the bearings. The disadvantage in this is self-evident. If anything should happen to the pump, the supply

of oil might be cut off long enough to cause considerable trouble before it was noticed, but with the reservoir system with its gauge constantly in sight, nothing like this is ever likely to happen. The most important part of a complete oiling system is unquestionably the filter, as its failure to perfectly purify the waste oil would cause the working parts of the machinery to be deluged with a dirty lubricant, not only increasing the friction and wear, but gradually filling up the pipes with sediment and choking off the feed.

In the duplex type of filter, the impure oil enters an auxiliary tank on the top of the filter, passing through a removable screen therein, and out through a spigot into a peculiar type of funnel, provided with a perforated conical foot. This funnel occupies a a rectangular compartment partially filled with water kept at a moderate temperature by means of a steam coil entering from the back. The waste oil descending through the funnel tube is discharged below the surface of the water in an upward direction, thus leaving the sediment at the bottom of the chamber undisturbed. By the continued action of the heat the oil becomes thin and all water and heavy impurities are gradually separated from it by gravity; the oil overflows from the separating chamber into adjacent filtering cylinders, which are formed of wire mesh and wrapped with several layers of specially prepared cloth, securely tied in position by stout cords. In its passage through the cloth the oil is entirely freed from every vestige of impurity not previously eliminated in the separating chamber by gravity. The object of having a duplex system is that during the cleaning, one filtering cylinder will be in active operation all the time, and the delivery of oil to the system need not be stopped for a moment. The filtering cloths when dirty are simply cleansed and dried, thus incurring no expense for filtering materials.

Briefly stated, the advantages are:

1. Wastage of oil is entirely eliminated. There is no handling of the oil beyond replenishing reservoir at long intervals. This does away with oil bespattered floors.

2. After oil passes through engine bearings it is discharged into the oil filter and thoroughly cleaned. This keeps the oil entirely free from all foreign matter.

3. A steady flow of oil is fed upon the bearings, regulated according to the requirements.

4. Attention reduced to minimum. The oil feeds require only occasional inspection

5. A given quantity of oil will last 50 per cent. longer than by hand oiling, and the saving from this source alone is sufficient to pay for the system's installation in a short time.

6. One or more engines may be connected to the same system.

ELECTRIC POWER TRANSMISSION.

Comprehensively considered, the transmission of power by electricity contemplates an equipment comprising the following elements:

Motive Power:

Water Wheels,
Steam Turbines,
Engines—Steam,
Gas,
Gasoline,
Kerosene.

(Driving by belts or ropes from pulleys is not considered, as they are merely features of transmission and not prime movers.)

Generators:

Direct Current,
Alternating Current,
Double Current (A. C. D. C.)

Transmission:

High Tension Switchboards and Instruments,
Step-up Transformers,
Conductors and Pole Lines,
Protection Against Lightning.

Distribution:

Sub-Stations, or Transformer Houses,
Step-down Transformers
Low Tension Switchboards and Instruments,
Wiring,
Rotary Converters.

Motors and Lights:

Direct Current Motors,
Induction Motors,
Synchronous Motors,
Arc and Incandescent Lighting.

The above represents a complete outfit for the generation, transmission, distribution, and application of electric power. All of these functions may or may not be included in one

Electric Power Transmission, Continued.

plant; they may be exercised by two different companies, one supplementing the other. For instance,—

One company may generate and transmit power for sale.
A consumer may purchase current for power and lighting.

As for the motive power, water wheels and steam engines have already been treated at length in the preceding pages. Gasoline, kerosene, and similar types of engines have as yet no place in the power plants of textile mills.

It is not unlikely that in the future gas engines will become an important factor as a motive power, particularly for electric transmission. The results already obtained encourage the belief that gas engines will sooner or later equal if not excel steam engines in economy. At the same time, the matter has not progressed far enough to warrant any more than passing mention of it in this book.

Steam turbines will be taken up in connection with generators.

The considerations affecting the choice of the type of apparatus are here considered, but a general discussion of the advantages of electric driving as compared to mechanical will follow later, as they are naturally brought out in the description of typical plants that is appended to this chapter.

While engineers hold divergent views upon the details of application, arrangement and disposition of the apparatus, but little or no difference of opinion exists as to the choice of the type of apparatus best adapted to mill work. A very good general idea, therefore, can be obtained of the machinery and appliances required for the electric driving of a modern cotton mill from the comparatively brief description given on the following pages.

It is not intended to adhere strictly to the sub-divisions given on the preceding page; these sub-divisions are made rather to make clear at a glance the details of the general subject.

Electric Power Transmission, Continued.

Different Systems.

Although the **Continuous**, or **Direct Current System** of electric power transmission has an extensive field of usefulness in other branches of industry, its use in the cotton mill trade is restricted to relatively small individual motors installed in connection with electric pumps and other similarly unimportant and auxiliary purposes. The principal objections to its use are :

(1). It is limited by the low potential for which commutating machines can be wound.

(2). The great cost of conductors necessary if the distances are considerable.

(3). That the sparking of motors of this type would be hazardous, even though inclosed in an iron-clad frame, is obvious from the very nature of the service.

(4). For any service whatever, one of the principal objections to the use of direct current apparatus is its complication : not only are there parts subject to wear that must be kept up and occasionally replaced, but also more repair parts must be kept in stock than in the case of alternating current apparatus.

In this book, therefore, transmission of power by alternating currents only will be considered.

Under the head of " Mill Lighting," however, direct current apparatus will be described, as it is the usual type of apparatus installed for small isolated plants of this character.

While the **Single Phase Alternating System** is largely used and well adapted to electric lighting, it is impracticable for power work, owing to the lack of a satisfactory self-starting motor.

It is true that single phase synchronous motors can be used when supplied with small starting motors, but while such apparatus is well enough when in use with old existing plants, its adoption in its present stage of development for a new plant would be contrary to the best practice.

The **Polyphase Alternating System**, however, is particularly well adapted to the generation, transmission, and distribution of power for both mill work and lighting. It possesses not only all the advantages of both the single phase alternating and the direct current systems, but many important advantages over both. It is unnecessary to enumerate the good points of this system in these introductory remarks, however, as they will be fully brought out in the general discussion of this subject that follows.

Electric Power Transmission, Continued.

THE POLYPHASE SYSTEM.

By the term "Polyphase System" is meant any arrangement of conductors carrying two or more single phase alternating currents definitely related to one another in point of time. The arrangements commonly employed are two phase and three-phase.

The two-phase system consists of two single phase circuits displaced ninety degrees from each other, and is sometimes termed the "quarter phase" system; the three-phase system consists of three single phase circuits displaced one hundred and twenty degrees from each other.

From the standpoint of distribution involving both lights and power, the two-phase system possesses certain advantages; but as the average cotton mill job is largely one of power, and generally one also of transmission, the three-phase system is the one usually adopted.

Just here it is well to state that in discussing two and three-phase systems, there is little to be said so far as the apparatus employed itself is concerned in one case that would not apply to the other; the differences are largely electrical ones. The mechanical details and even the dimensions are practically the same in both cases.

But when it comes to the question of transmission, there is this very material difference: That only three wires are needed in the one case as against four wires of the same size in the other. The three-phase three-wire system effects a saving of one quarter of the copper that would be required for a two-phase four-wire circuit, or a two-wire single-phase or direct current circuit, all of the same voltage.

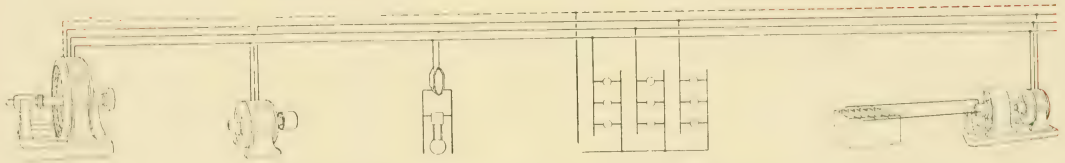
Briefly considered, polyphase power plants may be divided into three classes, in which:

(1). The generator delivers current directly to the distribution system at low potential and the generators are wound for just enough higher potential to take care of the losses in transmission.

(2). The generator delivers power to the distribution system at high potential and step-down transformers are used to lower the pressure to that of the motors and lights.

(3). The generator is wound for a low potential and transformers are employed to raise the pressure to that required for economical transmission and again to lower it for distribution.

Electric Power Transmission, Continued.



(1). The accompanying cut shows diagrammatically a plant of the first class. The generator is wound for 220 to 250 volts, and motors and lights are operated directly from it without intermediate transformers. In application it corresponds very closely to a direct current system, and is well adapted for mill work in which the distances over which the power is to be distributed are not great.

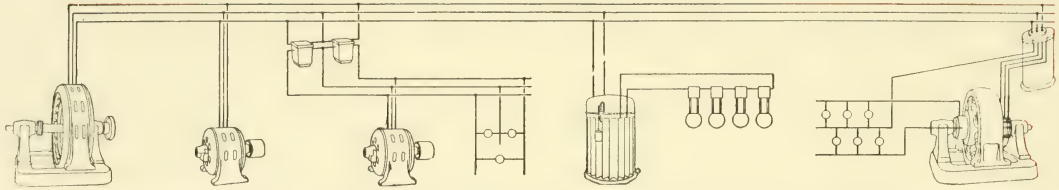
In the diagram a fourth wire is shown dotted in: this is sometimes used as a common return for lighting. It is hardly worth while more than simple mention, however, as ordinary mill work does not require its use.

In the case of voltage from 440 to 500, the diagram would be practically the same as the above, except for the incandescent lights, which would have to be operated through transformers.

Beginning at the left of the cut, the different apparatus is shown consecutively as follows:

A three-phase generator, an induction motor, a constant potential arc light with its transformer, incandescent lamps, and a motor-generator set furnishing direct current for electrolytic chemical work.

Electric Power Transmission, Continued.



(2). The above shows diagrammatically a plant of the second class. The generator is wound for 2200 to 2300 volts. Large motors may be operated directly at this voltage, but arc and incandescent lighting, small motors and rotary converters must all take their current through lowering transformers.

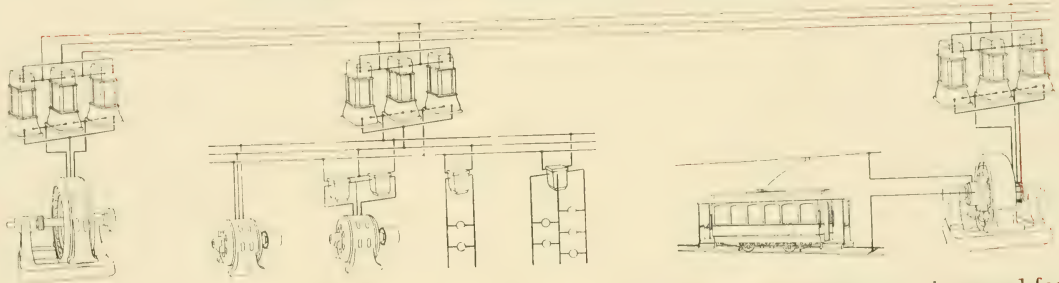
Beginning at the left of the cut, the different apparatus is shown consecutively as follows :

A three-phase generator, a moderate or large size high potential induction motor, small induction motors and incandescent lighting with their transformers, series arc lighting with its transformer, and incandescent lighting taking current from a rotary converter with its transformer.

Generators of large size can be wound for high potentials up to 10,000 to 13,000 volts, so that this system covers the greater portion of mill requirements and is that most generally used.

The large motors operated directly from very high tension circuits without intermediate transformers will of course have to be of very large size.

Electric Power Transmission, Continued.



(3). The above shows diagrammatically a plant of the third class. The generator is wound for moderate voltages, and delivers current to the transmission circuits through step-up transformers. As a general thing, the power is distributed from these transmission circuits at sub-stations through step-down transformers, in large units. From each sub-station other transmission circuits redistribute the power practically as in the second class shown on the preceding page.

The above description applies particularly to the case of a power company generating and transmitting current to distant points for sale.

Electric Power Transmission, Continued.

Frequency.—This may be designated either by the number of alternations per minute or cycles per second.

Each "alternation" corresponds to one variation of electro motive force, from zero to its maximum and back to zero, in either a positive or negative direction; the current "alternates" in polarity from positive to negative, flowing first in one direction, then in the other. The alternations per minute are determined by the product of the number of poles and the revolutions per minute.

Each "cycle" corresponds to one variation of electro motive force, from zero to its maximum and back to zero in both a positive and negative direction; cycles per second are determined by the product of the poles divided by two, and the number of revolutions per second.

In the early development of alternating apparatus, high frequency was the rule, because the problem was almost entirely one of lighting. High frequencies are generally understood to mean more than 7200 alternations per minute (60 cycles per second); 60 cycles and less are usually considered low frequencies. It is true that generators and transformers are cheaper for high frequencies than for low, and the operating of lamps, both incandescent and arc, also synchronous motors, is satisfactory. At the same time, the disadvantage of increased drop in voltage due to excessive reactance with consequent bad regulation and heating of generator at light loads; of not permitting the parallel operation of direct current generators of low speeds; and that induction motors must either run at excessive speeds or with poor power factors.—all constitute insurmountable objections to the use of high frequencies for both lights and power.

At the present time the standard frequencies are 25, 30, 40 and 60 cycles. For power purposes the lower frequency is better adapted, because of the higher power factor under which the motors operate. For lighting purposes, 60 cycles give better results. Arc lights do not operate satisfactorily on frequencies less than 40 cycles, nor incandescent lamps on less than 30 cycles.

The choice of frequency, therefore, depends largely upon the service. If it could be definitely and positively said that the service would be all power with no lighting, 25 to 30 cycles would be better; on the other hand, that is not a

Electric Power Transmission, Continued.

safe prediction at all. and therefore 40 to 60 cycles are recommended.

A number of cotton mills have installed 40 cycle plants that have been exceedingly satisfactory in operation : at the same time it is questionable if this practice should be continued, because at some time there might be a very great advantage in having interchangeable apparatus with power companies, which are generally of 60 cycles.

Voltage.—The classification of polyphase apparatus previously made will give a very good general idea of the voltage suited to different conditions. Primarily, however, it depends upon the distance over which the power is to be transmitted.

Long distance means high potentials, or the cost of conductors would become prohibitive. A given amount of power can be transmitted forty miles at 40,000 volts with no more loss and at no more cost for copper than the same amount of power ten miles at 10,000 volts.

Up to the present time plants have been installed with voltages up to 50,000. Eminent authority is of the opinion that we will yet see 100,000 volts handled with equal facility. There is no trouble whatever in building transformers for that potential already. The problem is largely one of transmission.

So much for the range in voltage and transmission circuits. When it comes to the distribution of power inside the mill, the voltage is confined to relatively narrow limits :

Where the voltage of the generator and the transmission circuits does not exceed 600, the distribution circuits to the motors will be of the same voltage.

Where the voltage of the transmission circuit exceeds 600

Electric Power Transmission, Continued.

volts, it should be lowered through step-down transformers to a voltage not exceeding 600 for the motors,—400 to 500 volts are standard.

Where the voltage of the transmission circuit exceeds 250 volts, the lamps must be fed through transformers.

The Cost of Conductors.—In order to determine the best potential, or voltage, for a power transmission, it is necessary to consider carefully the cost of the transmission circuit. The weight of the electric conductors decreases as the square of the potential employed and increases as the square of the distance. Dividing the potential by the distance gives a convenient figure which can be used for all potentials and distances. The curves on the following page, kindly furnished by the General Electric Company, are derived in this way and furnish a ready means of obtaining the amount of copper required for a given power transmission.

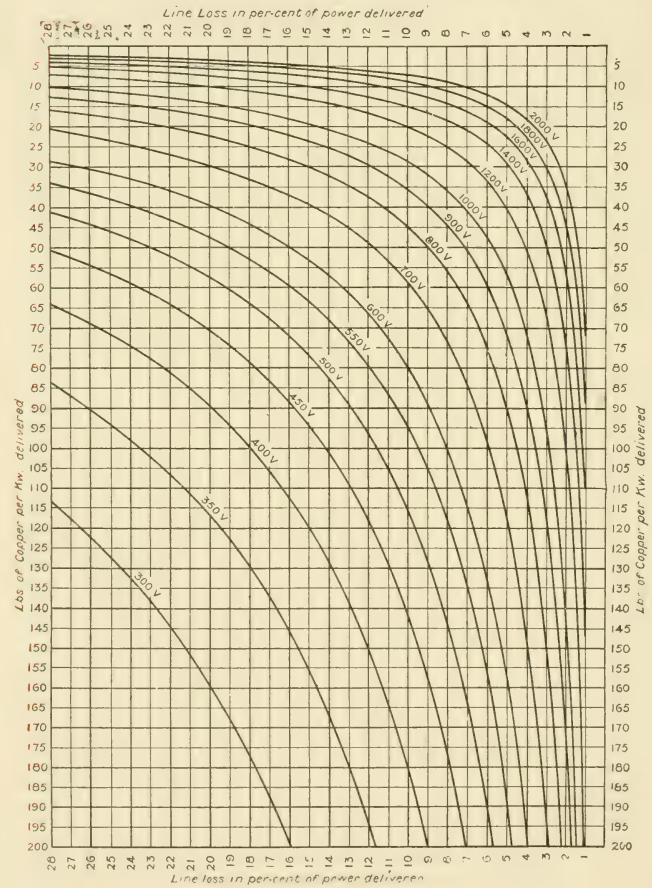
The figures on the curves indicate *volts per mile, i. e.*, potential of line at generator divided by distance in miles. The weight of copper, potential, and line loss are in terms of the power delivered at the end of the line, and not of generated power. The curves are correct only for three-phase current with 100% power factor. Two-phase, single-phase or continuous current transmission require one-third more copper. Five per cent. has been allowed for sag, in weights of copper given.

EXAMPLE: Assuming that 1000 K. W. at 10,000 volts are to be delivered over a line 10 miles long with 5% loss, we have $\frac{10{,}000 \text{ volts}}{10 \text{ miles}} = 1000$ volts per mile. Looking on the 1000 volt curve, we find 5% line loss corresponds to 57 lbs. of copper per kilowatt delivered.

1000 K. W. $\times$ 57 = 57,000 lbs. If copper costs 20 cents a lb. the cost will be 57,000 $\times$ \$.20 = \$11,400.

Electric Power Transmission, Continued.

Three-Phase Circuits—Weight of Copper per K. W. Delivered.



Electric Power Transmission, Continued.

General Wiring Formulas.

The General Electric Company's formulas for determining the size of Copper Conductors, volts loss in lines, current per conductor, and weight of copper per circuit for any system of electrical distribution, will be found very convenient:

$$\text{Area of conductor, Circular Mils} = \frac{D \times W \times C}{P \times E^2}$$

$$\text{Volts loss in lines} = \frac{P \times E \times B}{100}$$

$$\text{Current in main conductors} = \frac{W \times T}{E}$$

$$\text{Pounds copper} = \frac{D^2 \times W \times C \times A}{P \times E^2 \times 1{,}000{,}000}$$

W = Total watts delivered.
D = Distance of transmission (one way) in feet.
P = Loss in line in per cent. of power delivered, that is, of W.
E = Voltage between main conductors at receiving or consumer's end of circuit.
For continuous current C = 2160, T = 1, B = 1, and A = 6.04.

Table of Wiring Constants.

System.	Values of A.	Values of C. Per Cent. Power Factor.					Values of T. Per Cent. Power Factor.				
		100	95	90	85	80	100	95	90	85	80
Single-phase.....	6.04	2160	2400	2660	3000	3380	1.00	1.05	1.11	1.17	1.25
Two-phase (four-wire)...	12.08	1080	1200	1330	1500	1690	.50	.53	.55	.59	.62
Three-phase (three-wire)	9.08	1080	1200	1330	1500	1690	.58	.61	.64	.68	.72

Table of Wiring Constants, Concluded.

No of Wire B. & S. Gauge.	Diameter of Wire in Mils.	Area Wire in Circular Mils.	Weight of Bare Wire per 1000 feet, pounds.	Weight of Weather Proof Wire per 1000 feet, pounds.	Carrying Capacities. 32 degs. Cent. rise. Open Work.	Carrying Capacities. 16 degs. Cent. rise. Concealed Work.	Resistance of Wire per 1000 feet at 25° C. Ohms.	Values of B. 25 Cycles. Per Cent. Power Factor. 95	90	85	80	40 Cycles. Per Cent. Power Factor. 95	90	85	80	60 Cycles. Per Cent. Power Factor. 95	90	85	80
0000	460	212000	641	730	312	210	.0499	1.23	1.29	1.33	1.34	1.52	1.53	1 61	1.67	1.62	1.84	1.99	2.09
000	410	168000	509	590	262	177	.0628	1.18	1.22	1.24	1.24	1.40	1.41	1.48	1.51	1.49	1.66	1.77	1.95
00	365	133000	403	480	220	150	.0794	1.14	1.16	1.16	1.16	1.25	1.32	1.35	1.37	1.34	1.52	1.60	1.66
0	325	106000	320	390	185	127	.0997	1.10	1.11	1.10	1.09	1.19	1.24	1.26	1.26	1.31	1.40	1.46	1.49
1	290	83500	253	310	156	107	.126	1.07	1.07	1.05	1.03	1.14	1.17	1.18	1.17	1.24	1.30	1.34	1.36
2	258	66000	202	250	131	90	.159	1.05	1.04	1.02	1.00	1.11	1.12	1.12	1.10	1.18	1.23	1.25	1.26
3	230	52400	159	200	110	76	.202	1.03	1.02	1.00	1.00	1.07	1.08	1.07	1.05	1.14	1.17	1.18	1.17
4	205	41600	126	160	92	65	.254	1.02	1.00	1.00	1 00	1.05	1.06	1.03	1.00	1.11	1.12	1.11	1.10
5	182	33100	100	135	77	54	.319	1.00	1.00	1.00	1.00	1.03	1.01	1.00	1.00	1.08	1.08	1.06	1.04
6	162	26200	79.5	115	65	46	.403	1.00	1.00	1.00	1.00	1.02	1.00	1.00	1.00	1.05	1.04	1.02	1.00
7	145	20700	62.8	93	55	38	.510	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.00	1.03	1.02	1.00	1.00
8	129	16600	50.4	75	46	33	.635	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.02	1.00	1.00	1.00
9	115	13000	39.4	63	38	28	.813	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	102	10400	31.5	52	32	24	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

The above data refers to copper wire only.

Electric Power Transmission, Continued.

Wiring Formulas, Continued.

The following formula will also be found a convenient one for calculating the copper required for long distance three-phase transmission circuits :

$$\text{Lbs. Copper} = \frac{M^2 \times K.W. \times 300{,}000{,}000}{P \times E^2}$$

M is the distance of transmission in miles, K. W. the power delivered in Kilowatts and the power factor is assumed to be approximately 95%.

Application of Formulas.

The value of C for any particular power factor is obtained by dividing 2160, the value for continuous current, by the square of that power factor for single-phase, and by twice the square of that power factor for three-wire three-phase, or four-wire two-phase.

The value of B depends on the size of wire, frequency and power factor. It is equal to I for continuous current, and for alternating current with 100 per cent. power factor and sizes of wire given in the preceding table of wiring constants.

The figures given are for wires 18 inches apart and are sufficiently accurate for all practical purposes provided the displacement in phase between current and E. M. F. at the receiving end is not very much greater than that at the generator; in other words, provided that the reactance of the line is not excessive, or the line loss unusually high. For example, the constants should not be applied at 125 cycles if the largest conductors are used and the loss 20% or more of the power delivered. At lower frequencies, however, the constants are reasonably correct even under such extreme conditions. They represent about the true values at 10% line loss, are close enough at all losses less than 10%, and often, at least for frequencies up to 40 cycles, close enough for even much larger losses. Where the conductors of a circuit are nearer each other than 18", the volts loss will be

Electric Power Transmission, Continued.

Wiring Formulas, Concluded.

less than given by the formulas, and if close together, as with multiple conductor cable, the loss will be only that due to resistance.

The value of T depends on the system and power factor. It is equal to I for continuous current and for single-phase current of 100 per cent. power factor.

The value of A and the weights of the wires in the table are based on .00000302 lbs. as the weight of a foot of copper wire on one circular mil area.

In using the above formulas and constants, it should be particularly observed that P stands for the per cent. loss in the line of the delivered power, not for the per cent. loss in the line of the power at the generator ; and that E is the potential at the end of the line and not at the generator.

When the power factor cannot be more accurately determined, it may be assumed to be as follows for any alternating system operating under average conditions : Incandescent lighting and synchronous motors, 95% : lighting and induction motors together, 85% ; induction motors alone, 80%.

The three wires of a three-phase circuit and the four wires of a two-phase circuit should all be made the same size and each conductor should be of the cross-section given by the first formula.

Inside Wiring.

Tables of Distances at Various Percentages of Loss for 3-Phase Induction Motors.

The Westinghouse Electric & Manufacturing Company have furnished the following tables showing the distances in feet at various percentages of loss that wires of different sizes will deliver the current required for standard sizes of motors at 400 and 500 volts.

The proper allowance has been made in each case for the full load efficiency and power factor of the motor, so that the distance is for horse power at the motor shaft.

The sizes of wires are for each of the three wires in the circuit based upon a distance apart of approximately five inches.

For outside wiring strung on poles (transmission circuits) the preceding tables and formulas are to be used.

Electric Power Transmission, Continued.

Inside Wiring, Continued.

Distances in feet at Various Percentages of Loss.

10 H. P. 3-Phase Induction Motors.

Sizes of Wire, B. & S. Gauge.	At 400 Volts.					At 500 Volts.				
	1%	2%	3%	4%	5%	1%	2%	3%	4%	5%
0000	3140	6280	9420	12560	16500	4900	9800	14700	19600	25500
000	2500	5000	7500	10000	13100	3900	7800	11700	15600	20300
00	1975	3950	8925	7900	10400	3060	6120	9180	12240	16000
0	1570	3140	4710	6280	8250	2450	4900	7350	9800	12750
1	1250	2500	3750	5000	6550	1950	3900	5850	7800	10150
2	987	1975	2961	3950	5020	1530	3060	4590	6120	8000
3	785	1570	2355	3140	4125	1225	2550	3675	4900	6375
4	625	1250	1875	2500	3275	975	1950	2925	3900	5075
5	493	987	1479	1975	2510	765	1530	2295	3060	4000
6	392	785	1176	1570	2062	612	1225	1837	2450	3187
7	312	625	936	1250	1637	487	975	1462	1950	2537
8	247	493	741	987	1205	382	765	1148	1530	2000
9	....	....	....	.....	.....	306	612	918	1225	1593
10	....	....	....	.....	.....	244	487	731	975	1268

20 H. P. 3-Phase Induction Motors.

0000	1610	3220	4830	6440	8390	2500	5000	7500	10000	13100
000	1280	2560	3840	5120	6700	2000	4000	6000	8000	10450
00	1010	2020	3030	4040	5280	1575	3150	4725	6300	8200
0	805	1610	2415	3220	4195	1250	2500	3750	5000	6550
1	640	1280	1920	2560	3355	1000	2000	3000	4000	5225
2	505	1010	1515	2020	2640	787	1575	2361	3150	4100
3	402	805	1206	1610	2097	625	1250	1875	2500	3275
4	320	640	960	1280	1677	500	1000	1500	2000	2612
5	252	505	756	1010	1320	393	787	1179	1575	2050
6	201	402	603	804	1048	312	625	937	1250	1637
7	160	320	480	640	838	250	500	750	1000	1306
8	126	252	378	505	660	196	393	589	787	1025
9	....	....	....	....	....	156	312	468	625	818
10	....	....	....	....	....	125	250	375	500	653

30 H. P. 3-Phase Induction Motors.

0000	1080	2160	3240	4320	5690	1700	3400	5100	6800	8820
000	861	1722	2583	3444	4530	1350	2700	4050	5400	7040
00	681	1362	2043	2724	3580	1070	2140	3210	4280	5550
0	540	1080	1620	2160	2895	850	1700	2550	3400	4410
1	430	861	1290	1722	2265	675	1350	2025	2700	3520
2	340	681	1020	1362	1790	535	1070	1605	2140	2775
3	270	540	810	1080	1447	425	850	1275	1700	2205
4	215	430	645	861	1133	337	675	1011	1350	1760
5	170	340	510	681	895	268	535	804	1070	1387
6	....	....	....	....	....	212	425	637	850	1102
7	....	....	....	....	....	168	337	505	675	880

Electric Power Transmission, Continued.

Inside Wiring, Continued.

Distances in feet at Various Percentages of Loss.

40 H. P. 3-Phase Induction Motors.

Sizes of Wire, B. & S. Gauge.	At 400 Volts.					At 500 Volts.				
	1%	2%	3%	4%	5%	1%	2%	3%	4%	5%
0000	815	1630	2445	3260	4290	1275	2550	3825	5100	6550
000	650	1300	1950	2600	3420	1020	2040	3060	4080	5300
00	515	1030	1545	2060	2700	804	1608	2412	3216	4180
0	408	815	1224	1630	2145	637	1275	1901	2550	3325
1	325	650	975	1300	1710	510	1020	1530	2040	2650
2	257	515	771	1030	1350	402	804	1206	1608	2090
3	204	408	612	815	1072	318	637	954	1275	1662
4	163	325	489	650	855	255	510	765	1020	1325
5	....	....	....	....	....	201	402	603	804	1045

50 H. P. 3-Phase Induction Motors.

0000	670	1340	2010	2680	3520	1050	2100	3150	4200	5400
000	534	1068	1602	2136	2820	832	1664	2496	3328	4350
00	422	844	1266	1688	2220	660	1320	1980	2640	3420
0	335	670	1005	1340	1760	525	1050	1575	2100	2700
1	267	534	801	1068	1410	416	832	1248	1664	2175
2	211	422	633	844	1110	330	660	990	1320	1710
3	167	335	502	670	880	262	524	786	1048	1350
4	....	....	...	....	....	208	416	624	832	1087
5	....	....	....	....	....	165	330	395	660	855

75 H. P. 3-Phase Induction Motors.

0000	451	902	1353	1804	2380	705	1410	2115	2820	3670
000	360	720	1080	1440	1900	564	1128	1692	2250	2940
00	284	568	852	1136	1500	444	888	1332	1776	2320
0	225	451	675	902	1190	352	704	1056	1408	1830
1	....	....	....	....	....	282	564	846	1128	1470
2	....	....	....	....	....	222	444	666	888	1160

Electric Power Transmission, Continued.

Inside Wiring, Concluded.

Distances in feet at Various Percentages of Loss.

100 H. P. 3-Phase Induction Motors.

Sizes of Wire, B. & S. Gauge.	At 400 Volts.					At 500 Volts.				
	1%	2%	3%	4%	5%	1%	2%	3%	4%	5%
2-0000	698	1396	2094	2792	3650	1092	2184	3276	4368	5680
2-000	558	1116	1674	2232	2910	870	1640	2610	3280	4520
2-00	440	880	1360	1760	2300	688	1376	2064	2752	3580
0000	349	698	1047	1396	1825	546	1092	1638	2184	2840
000	279	558	837	1116	1455	435	870	1305	1640	2260
00	220	440	660	880	1150	344	688	1034	1376	1790
0	....	....	....	....	....	273	546	819	1092	1420

150 H. P. 3-Phase Induction Motors.

2-0000	464	928	1392	1856	2440	728	1456	2184	2912	3640
2-000	370	740	1110	1480	1950	578	1156	1734	2312	2900
2-00	292	584	876	1168	1438	460	920	1380	1840	2290
0000	232	464	696	928	1220	364	728	1092	1456	1820
000	....	....	..	....	...	289	578	867	1156	1450

200 H. P. 3-Phase Induction Motors.

2-0000	349	698	1047	1396	1825	540	1080	1620	2160	2820
2-000	279	558	837	1116	1455	428	856	1284	1712	2250
2-00	220	440	660	880	1150	340	680	1020	1360	1790
0000	..	....	....	...	....	270	540	810	1080	1410

Electric Power Transmission, Continued.

Aluminum Conductors.

Copper conductors have been largely used in the past for both transmission and distribution circuits. In the future, however, the probability is that aluminum will be used largely for the transmission circuits, though copper will probably continue to be used for the distribution circuits. An aluminum conductor of the same conductivity at the present price of copper costs somewhat less than copper and possesses certain other advantages. In comparing the sizes of aluminum and copper wires of the same resistance and conductivity, it will be found that an aluminum wire of 156,500 circular mils area possesses the same resistance as a copper wire of 100,000 circular mils area. This ratio is approximately the same as that between wires separated by one number B. & S. gauge. Thus, a No. 1 aluminum wire is approximately the equivalent of a No. 3 copper wire; a No. 2 aluminum wire is approximately the equivalent of a No. 4 copper wire; etc. For the same conductivity an aluminum wire is only forty-seven per cent. of the weight of the same length of a copper wire. The difficulty in the use of aluminum wires for distribution lies in the difficulty of making joints; this is a matter of small consequence in transmission circuits, because the joints there are generally made by clamps. For distribution circuits, the soldered joints of copper are more conveniently and easily made. The following tables give comparative dimensions and weights of aluminum and copper wires.

Electric Power Transmission, Continued.

Table of Dimensions and Weights of Aluminum and Copper Wire.

Specific Gravity of Aluminum taken as 2.68, water weighing 62.355 pounds per cubic foot. Specific Gravity of Copper, 8.93.

Am. Gauge, B. & S. No.	Diam. Mils.	Circular Mils, (d^2) 1 Mil. = .001 Inch.	Weight of Bare Wire. Pounds per Mile, Alum'n.	Pounds per Mile, Copper.	Feet per Pound Alum'n.	Feet per Pound Copper.
0000	460.000	211600.00	1018.30	3393.07	5.185	1.728
000	409.640	167805.00	807.52	2690.75	6.539	2.179
00	364.800	133079.40	640.36	2133.74	8.246	2.748
0	324.860	105534.00	507.83	1692.14	10.397	3.465
1	289.300	83694.20	402.81	1342.21	13.108	4.368
2	257.630	66373.00	319.44	1064.39	16.529	5.508
3	229.420	52634.00	253 55	843.96	20 846	6.946
4	204.310	41742.00	200.90	669.44	26.281	8.757
5	181.940	33102.00	159.30	530.79	33.146	11.044
6	162.020	26250 50	126.35	421.02	41.789	13.924
7	144.280	20816.00	100.21	333.93	52.687	17.556
8	128.490	16509.00	79.46	264.78	66.445	22.140
9	114.430	13094.00	62.99	209.90	83.822	27.931
10	101.890	10381.00	49.95	166.49	105.68	35.215
11	90.742	8234 00	39.63	132.04	133.24	44.39
12	80 808	6529.90	31.43	104.71	168.01	55.98
13	71.961	5178.40	24.92	83.02	211.86	70 595
14	64.084	4106.80	19.76	65 83	267 17	89.02
15	57.068	3256.70	15.67	52.22	336.93	112.27
16	50.820	2582 90	12.43	41.42	424.81	141.55
17	45 257	2048.20	9.857	32.85	535.62	178.47
18	40.303	1624 30	7.814	26 04	675.67	225.14
19	35.890	1288.10	6.199	20.65	851.79	283.82
20	31.961	1021.50	4.916	16 38	1074 11	357.91
21	28.462	810.10	3.898	12.99	1354.65	451.38
22	25 347	642.70	3.091	10.30	1707.94	569.10
23	22 571	509.45	2.451	8.169	2153.78	717.66
24	20.100	404.01	1.944	6.478	2715 91	904.97
25	17.900	320.40	1.542	5.138	3424.66	1141.1
26	15.940	254 01	1.223	4.075	4317 78	1438.7
27	14.195	201.50	.9694	3.230	5446.63	1814.9
28	12.641	159.79	.7688	2.562	6868.13	2288.5
29	11.257	126.72	.6098	2.032	8698.03	2884 9
30	10.025	100.50	.4836	1.612	10917.0	3637.7
31	8.928	79.71	.3836	1 278	13762.8	4585.9
32	7.950	63 20	.3041	1.013	17361.1	5787.0
33	7.080	50.13	.2412	.8039	21886.7	7292 0
34	6.304	39.74	.1912	6373	27609 1	9199.6
35	5.614	31.52	.1517	.5055	34807.3	11627.4
36	5.000	25 00	.1203	.4010	43878.9	14620.6
37	4.453	19.83	.0954	.3179	55340 4	18440.0
38	3.965	15 72	.0757	.2521	69783.7	23252.6
39	3 531	12.47	0600	.1999	88028.2	29331.0
40	3.144	9.89	.0475	.1584	111099.0	37019 2

Electric Power Transmission, Continued.

The Pole Line.

A few suggestions on this point are probably not out of place. Red cedar poles are expensive, but will greatly outlast any other kind. In comparing simply the cost of the poles, this may not be considered much of an item, but when the cost of resetting and connecting is considered, this item becomes very important. Poles for transmission circuits should have tops not less than six inches in diameter, and should be set about 125 feet apart on level ground.

For insulators, the Imperial No. 0 is very satisfactory ; its dimensions are as follows: Diameter, 6½″, height, 4¾″, surface distance, 8″, groove for wire, ½″, weight, 2⅜ lbs., and test voltage 55,000.

As for the disposition of the wires on the cross arms, either one of the three arrangements shown on the opposite page is recommended,—all of them are balanced arrangements for three-phase circuits, so disposed as to avoid mutual induction.

The distances apart shown are standard for voltages up to 5000 ; the wires must be spread farther apart for higher voltages, —which distances should be determined by experts familiar with all the conditions.

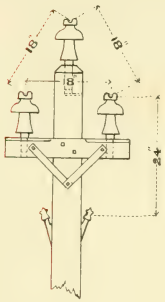
In any case the different wires must be gradually rotated or transposed through two complete turns between the generator and the first sub-station or branching-off point, and two reversals between succeeding branching-off points. The two different circuits should be rotated in opposite directions.

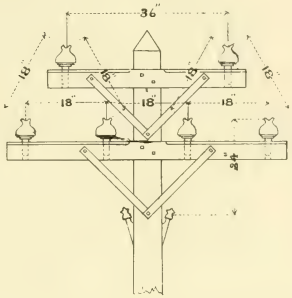
It is perhaps of interest to note that not only is there no mutual induction in the case of circuits so transposed, but the currents will not materially interfere with a telephone line which may be run on the same poles. In fact, these telephone lines should be run on the same poles to connect the generator station with the sub-stations, as a matter of convenience.

The No. 1 arrangement shown is seldom recommended. The No. 2 or No. 3 arrangement is much better even if only one circuit is to be run in the beginning,—thereby leaving room on the cross arms for an additional circuit to be run at any time in the future that the occasion may demand. The additional cost for longer cross arms is hardly worth considering.

Electric Power Transmission, Continued.

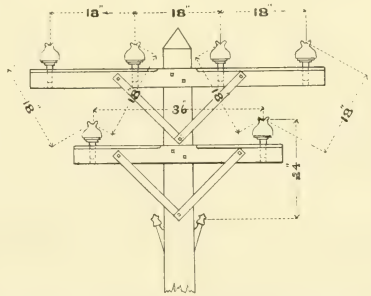
The Pole Line, Concluded.





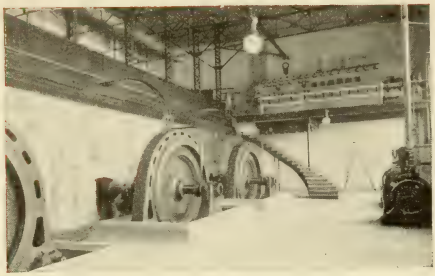
No. 1 Arrangement.—This is a convenient and cheap arrangement where only one circuit is to be run of three wires.

No. 2 Arrangement.—This is a very convenient arrangement where two transmission circuits are to be run of three wires each.



No. 3 Arrangement.—This is practically the same as the second arrangement, but probably better.

Note.—In each case the brackets below are for the telephone wires. A short arm may be substituted for the brackets shown above: the 24″ shown is minimum; 36″ to 60″ is better. Transpose telephone wires every fourth pole.



General Electric Three-Phase Alternators, Revolving Field Type, Direct Connected to Water Wheels.

POLYPHASE GENERATORS.

Generators may be divided into two general types, mechanically considered :

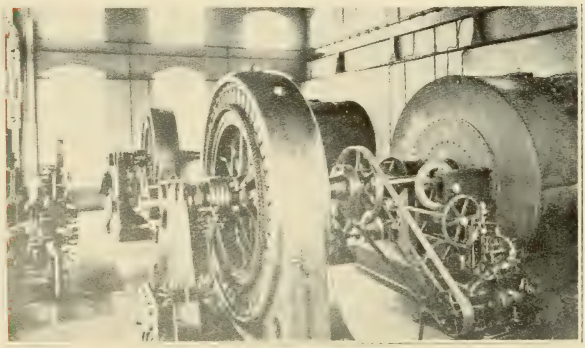
(1). **Belted Type**, comprising machines with two or three bearings and pulleys for belt driving.

(2). **Direct-Connected Type**, comprising those with bearings for coupling direct to a water wheel shaft ; and those without bearings for mounting directly on an engine shaft.

Electrically considered, both of these types are still further sub-divided into,—

(a) **Revolving Armatures.**

(b) **Revolving Fields.**

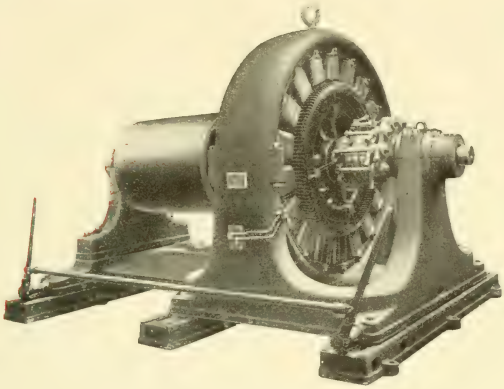


Westinghouse Two-Phase Alternators, Revolving Armature Type, Direct Connected to Water Wheels.

Electric Power Transmission, Continued.

Polyphase Generators, Continued.

Westinghouse Revolving Armature Belted Type.



(350 K. W. Three-Phase Generator.)

The general appearance of these generators is shown in the above cut. The lower half of the field and the supports of the bearings constitute a single casting. The pole-pieces are of soft laminated steel, cast into the field yoke or frame. The bearings are self-aligning and self-lubricating. The armature coils lie in slots and no band wires are used. The field and armature coils are wound upon moulds or formers and thoroughly insulated before they are put in place.

In many of the larger machines of 220 and 440 volts the armature conductors consist of copper bars placed in partially closed slots, the bars being held in place by the overhanging tips of the armature teeth. The bars are united into a common winding by suitable end connectors. Any bar may be removed and replaced by a new one without interfering with other bars.

Electric Power Transmission, Continued.

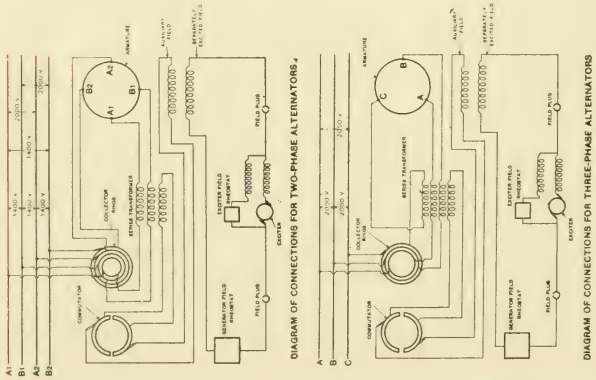
Revolving Armature Polyphase Generators, Continued.

The armature winding is of the closed circuit type. In the two-phase generators connection is made to the winding at four points, and an insulated conductor conveys the current from each of these points to one of the four collector rings. In the case of three-phase generators the winding is similar, but connection is made at three points to three collector rings. The connections of the armature winding, auxiliary field winding, collector rings and circuits are illustrated in the following diagrams.

The field excitation is chiefly derived from a separate exciter.

On all sizes smaller than 300 K. W. the fields are composite wound: in addition to the excitation from the separate exciter there is an auxiliary field current derived from the main current and proportional to it.

The current which passes through the auxiliary field winding is not the high potential current generated in the armature. It is a low potential current derived from the secondary of a series transformer, consisting of primary and secondary coils, wound upon the arms of the armature spider. In the case of the two-phase generators both phases are represented in the primary circuits of the transformer, while in the three-phase generators all three phases are represented. The compensation, therefore, depends upon the sum of the currents flowing in the several circuits supplied by the armature. The small commutator, used to rectify the derived secondary current which excites the auxiliary field coils, is carried upon the armature shaft.



(Westinghouse.)

Electric Power Transmission, Continued.

Revolving Armature Polyphase Generators, Continued.

Two-Phase Alternators.—The two-phase alternators are of the closed coil type, with four terminals. Referring to the diagram on opposite page in a 2000 volt generator the electro-motive force between A_1 and A_2 is 2000 volts, and between B_1 and B_2 is 2000 volts. The electro-motive force between any other pair of terminals is 1400 volts. If the electro-motive force is raised or lowered the same proportions hold, and for a 1000-volt machine the electro-motive forces are, respectively, 1000 and 700 volts. In practice potentials from five to ten per cent. higher than these figures are generally used at the generator.

Current in the circuit A_1-A_2 is at 90 degrees, or quarter phase, from current in the circuit B_1-B_2. These two circuits may therefore be used for operating motors. The four leads from the generator are connected to the switchboard. The potentials existing between any two of these leads are indicated in the diagram on opposite page.

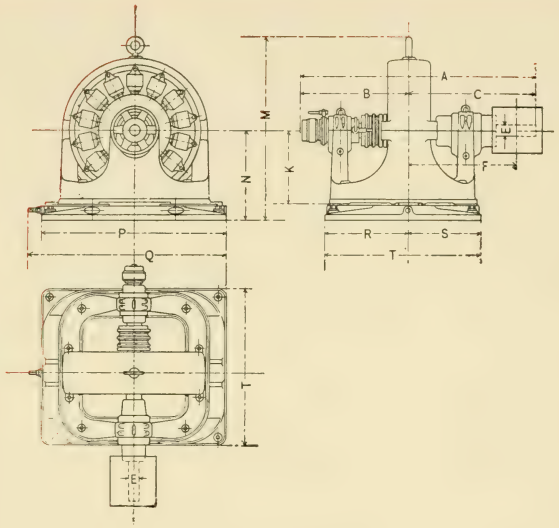
Three-Phase Alternators.—The three-phase alternators are of the closed coil type, with three terminals. Referring to the diagram on opposite page the electro-motive force between A and B is 2000 volts: between B and C is 2000 volts, and between C and A is 2000 volts. In practice a somewhat higher potential (say 2,100 or 2,200 volts) will be ordinarily carried at the generator. The current in each of the three circuits is at 120 degrees from the currents in the other two circuits. The three leads from the generator are connected to the switchboard.

In the distributing circuits ordinarily used in the three-phase system, transformers having a ratio of 2000/200 or 2000/100 volts are employed. Motors are usually connected to 200 volt circuits, incandescent and arc lamps to 100 volt circuits; the arc lamps being supplied with suitable voltage by means of economy coils.

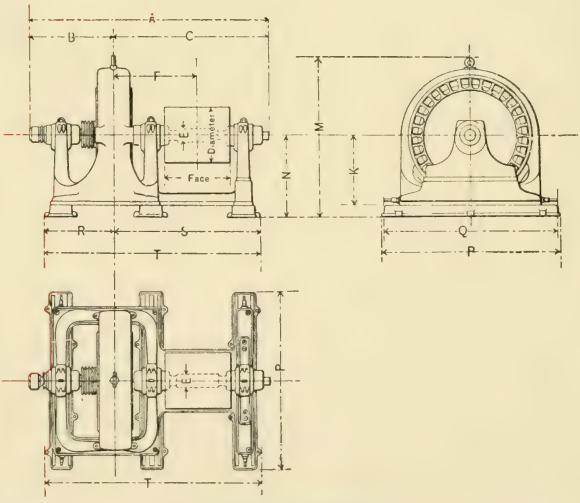
On the following pages are the standard sizes of alternators of this type. They are all built for 220, 440, 1100 and 2200 volts.

Machines up to and including 180 K. W. have two bearings; those of greater capacity have three bearings.

Westinghouse Revolving Armature Polyphase Generators, Continued.



(Two-Bearing Machines.)



(Three-Bearing Machines.)

Table of Approximate Dimensions, in Inches.

Westinghouse Rotary Armature Two-Bearing Alternators, 7200 Alternations, 60 Cycles.

K. W.	No. of Poles	R. P. M.	A	B	C	E	F	K	M	N	P	Q	R	S	T	Pulley			Keyway in Shaft	
																Diam.	Face	Length of Hub	Width	Depth
50	8	900	70 11/16	36 15/16	33 3/4	3 1/8	29 1/4	19 1/2	46 1/2	23 1/2	46 3/4	51 1/4	28 1/4	20 7/8	49 1/8	18	12	8	3/4	1/4
* 60	8	900	65 7/8	34 3/4	30 1/8	2 7/8	27	19 1/2	47 1/8	24 7/8	45 5/8	50 1/8	20 1/16	20 1/16	41 1/8	20	11	7	3/4	5/16
75	10	720	82 5/16	41 5/16	41 1/4	3 5/8	36 1/4	23 1/4	55 1/8	27 3/4	55	60	32	25 1/16	57 1/16	25	15	9	7/8	3/8
120	10	720	91 1/2	44 1/2	47	4 1/8	40 1/2	29	65 1/8	34	64 1/2	69 1/2	31 3/4	27 1/4	61 1/2	25	17	12	1 1/16	11/32
180	14	514	100 3/4	49 5/8	51 1/8	4 7/8	42 1/4	30	71 3/4	35	72	77	36 5/16	27 5/16	64 3/8	35	25	15	1 1/4	7/16
Three-Bearing Alternators.																				
250	16	450	155	57 1/2	97 1/2	7	53 1/2	39	85 3/4	46	98	89 1/4	46 3/8	90 3/8	136 3/4	40	38	25	1 3/4	13/32
300	24	300	162	53 1/2	108 1/2	7 3/4	58 1/2	47	109 1/2	54	113	114 3/4	47 3/4	102 3/4	150 1/2	45	50	32	1 7/8	7/16
325	22	327	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
350	20	360	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
400	18	400	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
400	16	450	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
450	14	514	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
500	26	277	168 1/2	58	110 1/2	8 1/4	61 1/2	64 1/2	134	72	142	132 3/8	54 1/8	106 5/8	100 3/4	60	46	32	2 1/8	1 1/16
600	22	327	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
650	28	257	190	"	132	8 7/8	70 1/2	72	147	79 1/2	"	140 1/4	52 1/8	120 1/8	178 1/4	60	66	44	"	"
650	20	360	190 1/2	"	132 1/2	8 1/4	72 1/2	64 1/2	134	72	"	132 3/8	51 1/8	128 5/8	182 3/4	45	65	"	"	"
700	26	277	190	"	132	8 7/8	70 1/2	72	147	79 1/2	"	140 1/4	52 1/8	126 1/8	178 1/4	60	66	"	"	"
700	18	400	190 1/2	"	132 1/2	8 1/4	72 1/2	64 1/2	134	72	"	132 3/8	51 1/8	128 5/8	182 3/4	45	65	"	"	"
750	22	327	190	"	132	8 7/8	70 1/2	72	147	79 1/2	"	140 1/4	52 1/8	126 1/8	178 1/4	60	66	"	"	"
800	20	360	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"

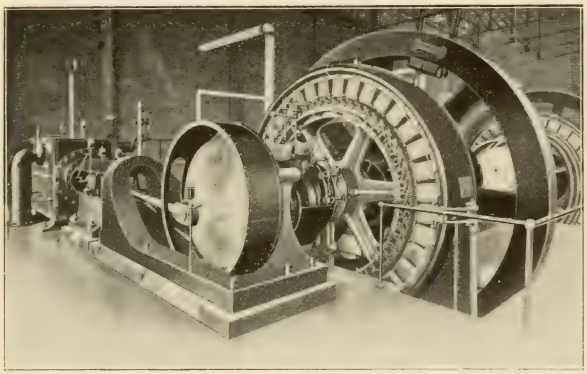
* NOTE.—This machine has the collector rings outside of bearings. The other machines in this table have the collector rings inside the bearings.

NOTE.—All machines of 250 K. W. and under are composite wound.

Electric Power Transmission, Continued.

Polyphase Generators, Continued.

Westinghouse Revolving Armature Engine Type.



(Westinghouse.)

This class, consisting of machines without bearings, is for direct connection to engines, usually of the cross compound type, in which case the main engine bearings are used for the support of the revolving parts. These engines may be either horizontal or vertical.

The revolving armature consists of a cast iron spider upon the outside of which a laminated steel rim is built. The surface of the armature is grooved in a direction parallel to the shaft by a large number of openings, or slots, and these are intersected at right angles by other openings, which extend around the armature. The former are for the reception of the insulated conductors, forming the winding; the latter, for the purpose of securing thorough ventilation of both core and windings.

By the use of laminated poles and numerous slots, the losses in the pole faces have been reduced to the lowest practicable limits.

The losses in the armature and field coils, and the armature iron loss have also been reduced to a minimum.

No table of sizes and dimensions of this type of machine is given, as we recommend the revolving field type for direct connection.

Electric Power Transmission, Continued.

Section of Strap Wound Rotating Armature.

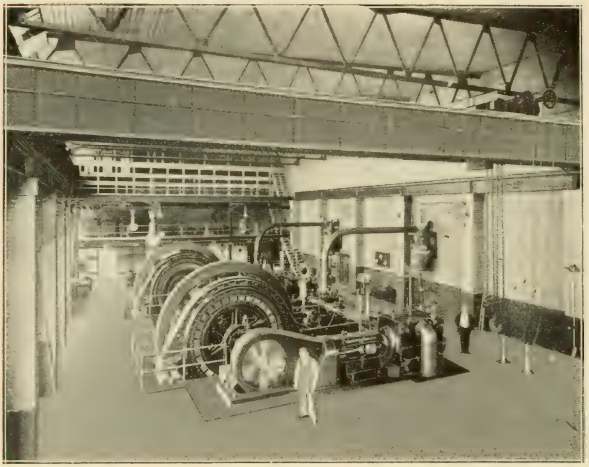
Section of Bar Wound Rotating Armature.

The armature winding consists of wire, strap, or bars, depending somewhat on the amount of current to be carried. The wire winding, which is usually employed in high voltage alternators of small current capacity, consists of machine wound coils which are carefully insulated before being placed in the armature slots. The strap winding used in alternators of lower voltage and greater current capacity consists of copper straps bent into the required shape and carefully insulated. Both the wire and strap windings are placed in the slots without any mechanical bending, and there is therefore no possibility of damage to insulation.

In bar winding the bars after being carefully insulated are slipped into the slots from one end of the armature.

Polyphase Generators, Continued.

Westinghouse Revolving Field Engine Type.



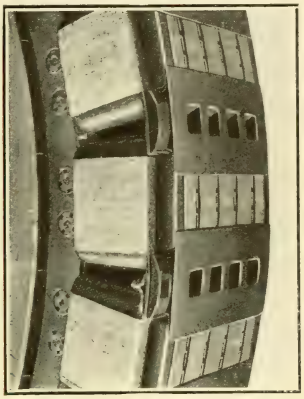
These machines are also without bearings for mounting direct on the engine shaft. Access to both the armature and the fields is obtained by sliding the stationary armature on foundation rails along the shaft.

In the revolving field alternator the armature is stationary and the field revolves. This method of construction facilitates the insulation of the armature winding and requires the field current instead of the armature current to pass through brushes and collector rings

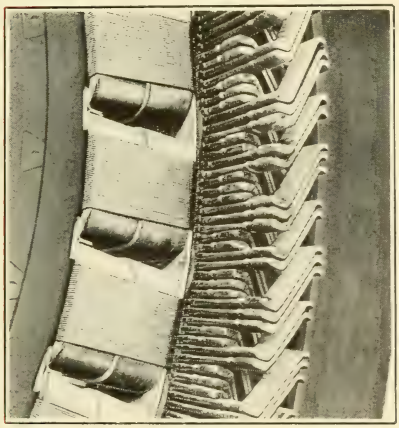
When completed the field is mounted upon the engine shaft. The construction of the field is such as to make a self-supporting steel rimmed fly wheel. The rim is of sufficient strength in itself to resist centrifugal force without bringing undue stress upon the central cast iron spider, the function of which is really to hold the outer rim in proper position. As there are ventilating discs in the pole pieces which register with those in the armature, constant circulation of the air through the armature core is secured.

The 5,000 K. W. generators in the Manhattan station, in New York City, are of this type. See page 618.

Electric Power Transmission, Continued.



A Portion of a Revolving Field Showing Coils in Place.



A Revolving Field and Stationary Armature.

The above cuts give a clear idea of the detail construction of a stationary armature and revolving field. The entire magnetic circuit, with the exception of the air gap, is composed of laminated steel, there being no machined joints to introduce uncertain resistances. The substantial construction insures safety at excessive speeds.

Electric Power Transmission, Continued.

Polyphase Generators, Westinghouse Revolving Field Engine Type, Continued.

Notes on Diagrams and Dimension Tables.

On the three following pages will be found diagrams and lettered dimension tables of Engine Type Revolving Field Alternators.

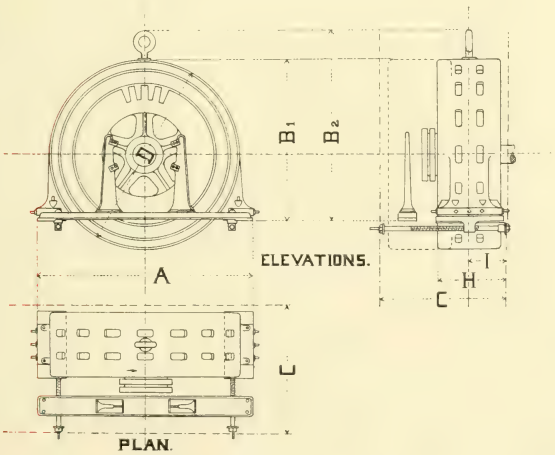
The dimensions are approximate only, and are intended simply for the convenience of engineers in laying out sketch plans and speculating upon power plant problems in a preliminary way. Of course, the space occupied by the generator is not to be added to the space required for an engine with the ordinary belt wheel; the wheels on direct connected engines being made with rims square in cross sections, and the allowance for space on the shaft depending upon the width of the hub, which is greater than that of the rim of the wheel. Experience only and a general knowledge of engine proportions will enable one to tell exactly what that would be. But, taken in connection with the tables on pages 636 to 643 inclusive, the data given, though meagre, is sufficient for an architect or engineer familiar with such work to approximate the floor space required for direct connected units of different sizes.

The Kilowatt rating is based upon 8% regulation at 100% power factor, with a 35 degree Centigrade rise in temperature above the surrounding air, which is assumed to be 25 degrees Centigrade. For a 25% over load of 24 hours duration, the rise will not exceed 45 degrees Centigrade; with a 50% overload, the rise will not exceed 55 degrees when in operation one to two hours, as the individual characteristics of the machines happen to be.

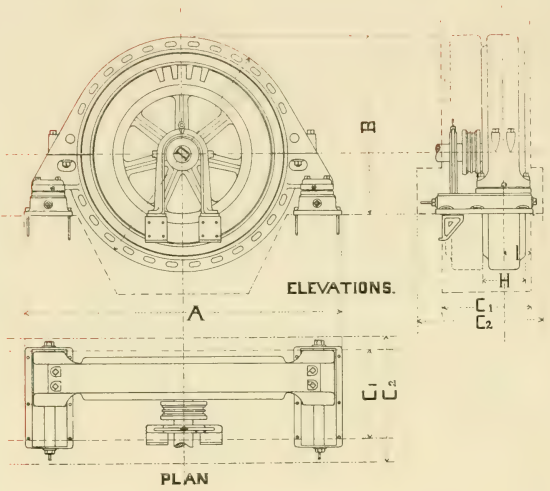
The tables cover only a partial list of machines of this type, for there is manifestly possible a practically unlimited number of sizes, as each machine of this type is specially built to suit the circumstances attending each individual case.

The dimensions and other data apply to either two or three phase machines of 60 cycles (7200 alternations), and voltages of 220 to 2200.

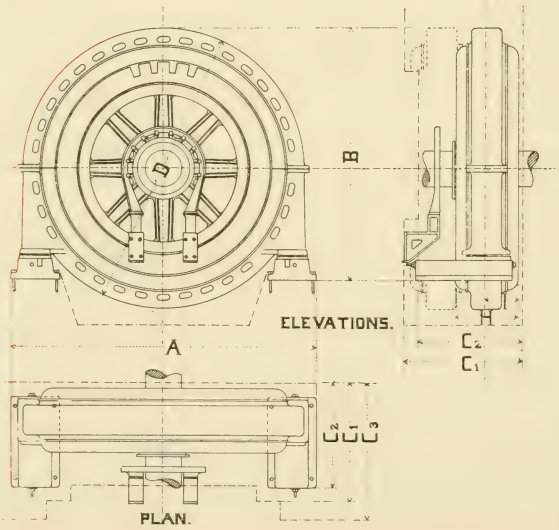
Note.—The collector rings and brush holders for the field currents are left off to better show the general field and armature construction.



Westinghouse Diagram No. 1.



Westinghouse Diagram No. 2.



Westinghouse Diagram No. 3.

Polyphase Generators,

Westinghouse Revolving Field Engine Type, Continued.

Table of Lettered Dimensions.

(In feet and inches.)

Moderate Speed Machines.

Rated Capacity in K. W.	Revolutions per Minute.	Diagram No.	A	B1	B2	C1	C2	D	H	I
90	225	1	6-7	5-0	5-10	4-1	....	5-10	2-1	1-4
105	257	1	6-7	5-0	5-0	4-1	....	5-10	2-1	1-4
135	300	1	6-7	5-0	5-10	4-1	....	5-10	2-1	1-4
140	112	3	11-1	9 5	. .	3-8	....	9-9	1-8	1-1
150	200	1	7-2	5 4	6-2	4-3	...	6-3	2-1	1-4
160	120	3	11-1	9-5	....	3-8	....	9-9	1-8	1-1
175	225	1	7-2	5-4	6-2	4-3	....	6-3	2-1	1-4
175	128	3	11-1	9-5	....	3-8	...	9-9	1-8	1-1
200	257	1	7 2	5-4	6-2	4-3	....	6-3	2-1	1-4
200	138	3	11-1	9-5	....	3-8	....	9-9	1-8	1-1
200	100	2	15-3	8-4	....	4-3	5-11	11-4	2-1	1-3
210	180	1	8-4	6-2	7-0	4-10	....	7-7	2-2	1-6
210	106	2	15-3	8-4	....	4-3	5-11	11-4	2-1	1-3
225	150	3	11-1	9-5	...	3-8	....	9-9	1-8	1-1
230	112	2	15 3	8-4	....	4-3	5-11	11-4	2-1	1-3
250	200	1	8-4	6-2	7-0	4-10	...	7-7	2-2	1-6
250	120	2	15 3	8-4	....	4-3	5-11	11-4	2-1	1 3
260	164	3	11-1	9-5	....	3-8	. ..	9-9	1-8	1-1
280	128	2	15-3	8-4	....	4-3	5-11	11-4	2-1	1-3
300	180	3	11-1	9-5	....	3-8	....	9-9	1-8	1-1
300	100	2	17-1	9 6	....	4-1	5-11	13-3	2-4	1-5
310	138	2	15-3	8-4	....	4-3	5-11	11-4	2-1	1-3
320	106	2	17-1	9-6	....	4-1	5-11	13-3	2-4	1-5
340	200	3	11-1	9 5	....	3-8	....	9-9	1-8	1-1
340	150	2	15-3	8-4	....	4-3	5-11	11-4	2-1	1-3
340	112	2	17-1	9-6	....	4-1	5-11	13-3	2-4	1 5
350	100	2	17-1	9-6	....	4-7	5-11	13-3	2-1	1-6
370	120	2	17-1	9-6	....	4 1	5-11	13-3	2-4	1-5
380	164	2	15-3	8-4	....	4-3	5 11	11-4	2-1	1-3
400	128	2	17-1	9-6	....	4-1	5-11	13-3	2-4	1-5
400	90	2	17-1	9-2	....	5-0	6-6	13-0	2-5	1-6
400	100	2	17-1	9-6	....	4-7	5-11	13-3	2-1	1-6
420	106	2	17-1	9-6	...	4-7	5-11	13-3	2-1	1-6
430	180	2	15-3	8-4	....	4-3	5-11	11-4	2-1	1-3
430	138	2	17 1	9-6	....	4-1	5-11	13-3	2-4	1-5
450	112	2	17-1	9-6	....	4-7	5-11	13-3	2-1	1-6
470	150	2	17-1	9-6	....	4-1	5-11	13-3	2-4	1-5
490	200	2	15-3	8-4	....	4-3	5-11	11-4	2-1	1-3
490	120	2	17-1	9-6	....	4-7	5-11	13-3	2-1	1-6
500	100	2	17-1	9-2	....	5-0	6-6	13-0	2-5	1-6
520	164	2	17-1	9-6	...	4-1	5-11	13 3	2-4	1-5
530	128	2	17-1	9-6	....	4-7	5-11	13-3	2-1	1-6
530	106	2	17-1	9-2	....	5-0	6-6	13-0	2-5	1-6
550	95	2	20-3	10-10	....	5-3	5-11	15-2	2-5	2-0
570	138	2	17-1	9 6	....	4-7	5-11	13-3	2-1	1-6
570	112	2	17-1	9-2	....	5-0	6-6	13-0	2-5	1-6
580	180	2	17-1	9-6	....	4 1	5-11	13-3	2-4	1-5

Polyphase Generators, Westinghouse Revolving Field Engine Type, Concluded.

Table of Lettered Dimensions, Continued.

(In feet and inches.)

Moderate Speed Machines, Concluded.

Rated Capacity in K. W.	Revolutions per Minute.	Diagram No.	A	B1	C1	C2	C3	D	H	I
600	100	2	20-3	10-10	5-3	5 11	....	15-2	2-5	2-0
620	150	2	17-1	9-6	4-7	5-11	....	13-3	2-1	1-6
620	120	2	17-1	9-2	5-0	6-6	....	13-0	2-5	1-6
650	200	2	17-1	9-6	4-1	5-11	....	13-3	2-4	1-5
660	106	2	20-3	10-10	5-3	5-11	....	15-2	2-5	2-0
670	128	2	17-1	9-2	5-0	6-6	....	13-0	2-5	1-6
690	161	2	17-1	9-6	4-7	5-11	....	13-3	2-1	1-6
720	112	2	20-3	10-10	5-3	5-11	....	15-2	2-5	2-0
730	138	2	17-1	9-2	5-0	6-6	....	13-0	2-5	1-6
740	180	2	17-1	9-6	4-7	5-11	. ..	13-3	2-1	1-6
750	95	2	21-6	11-8	4-10	5-8	....	16-6	2-3	1-5
780	120	2	20-3	10-10	5-3	5-11	.. .	15-2	2-5	2-0
800	150	2	17-1	9-2	5-0	6-6	....	13-0	2-5	1-6
803	100	2	21-6	11-8	4-10	5-8	....	16-6	2-3	1-5
850	200	2	17-1	9-6	4-7	5-11	....	13-3	2-1	1-6
850	128	2	20-3	10-10	5-3	5-11	....	15-2	2-5	2-0
850	106	2	21-6	11-8	4-10	5-8	....	16-6	2-3	1-5
880	164	2	17-1	9-2	5-0	6-6	....	13-0	2-5	1-6
920	138	2	20-3	10-10	5-3	5-11	....	15-2	2-5	2-0
920	112	2	21-6	11-8	4-10	5-8	....	16-6	2-3	1-5
950	95	3	18-7	15-0	6-0	5-1	6-7	16-10	2-10	1-9
980	180	2	17-1	9-2	5-0	6-6	....	13-0	2-5	1-6
1000	120	2	21-6	11-8	4-10	5-8	...	16-6	2-3	1-5
1000	100	3	18-7	15-0	6-0	5-1	6 7	16-10	2-10	1-9
1010	150	2	20-3	10-10	5-3	5-11	....	15-2	2-5	2-0
1060	128	2	21-6	11-8	4-10	5-8	....	16-6	2-3	1-5
1070	106	3	18-7	15-0	6-0	5-1	6-7	16-10	2-10	1-9
1100	200	2	17-1	9-2	5-0	6-6	....	13-0	2-5	1-6
1130	164	2	20-3	10-10	5-3	5-11	....	15-2	2-5	2-0
1140	112	3	18-7	15-0	6-0	5-1	6-7	16-10	2-10	1-9
1180	138	2	21-6	11-8	4-10	5-8	....	16-6	2-3	1-5
1240	120	3	18-7	15-0	6-0	5-1	6-7	16-10	2-10	1-9
1250	180	2	20-3	10-10	5-3	5-11	....	15-2	2-5	2-0
1290	150	2	21-6	11-8	4-10	5-8	....	16-6	2-3	1-5
1350	128	3	18-7	15-0	6-0	5-1	6-7	16-10	2-10	1-9
1400	200	2	20-3	10-10	5-3	5-11	....	15-2	2-5	2-0
1430	164	2	21-6	11-8	4-10	5-8	....	16-6	2-3	1-5
1470	138	3	18-7	15-0	6-0	5-1	6-7	16-10	2-10	1-9
1600	150	3	18-7	15-0	6-0	5 1	6-7	16-10	2-10	1-9
1700	95	3	20 4	16-6	7-11	6-10	9 1	18-6	4-4	2-5
1900	100	3	20-4	16-6	7-11	6-10	9-1	18-6	4-4	2-5
2000	106	3	20-4	16-6	7-11	6-10	9-1	18-6	4-4	2-5
2100	112	3	20-4	16-6	7-11	6-10	9-1	18-6	4-4	2-5
2300	120	3	20-4	16-6	7-11	6-10	9-1	18-6	4-4	2-5

Polyphase Generators, Westinghouse Revolving Field Engine Type, Concluded.

Table of Lettered Dimensions, Concluded.
(In feet and inches.)

Slow Speed Machines.

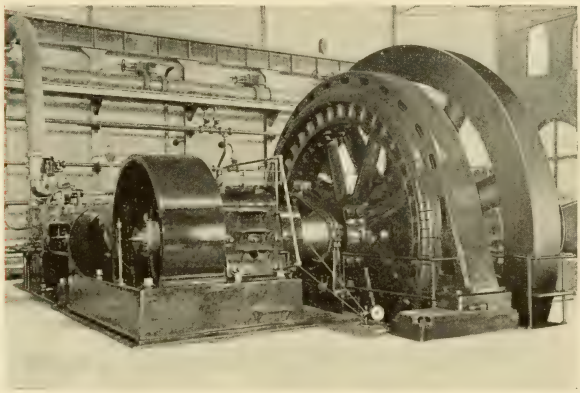
Rated Capacity in K. W.	Revolutions per Minute.	Diagram. No.	A	B	C_1	C_2	C_3	D	H	I
400	75									
415	76.5									
420	78									
430	80									
440	82	2	20-3	10-10	5-3	3-10	6-2	15-2	2-5	2-0
450	84									
460	86									
475	88									
500	90									
575	75									
590	76.5									
600	78									
615	80									
630	82	2	21-6	11-8	4-10	3-8	5-5	16-6	2-3	1-5
645	84									
660	86									
675	88									
700	90									
700	75									
715	76.5									
730	78									
750	80									
770	82	3	18-7	15-0	6-0	4-5	6-7	16-10	2-10	1-9
785	84									
805	86									
825	88									
850	90									
1300	75									
1330	76.5									
1360	78									
1390	80									
1425	82	3	20-4	16-6	6-9	4-4	8-9	18-6	3-1	1-10
1475	84									
1500	86									
1550	88									
1560	90									
2000	75									
2030	76.5									
2050	78									
2100	80									
2125	82	2	26-7	14-8	8-1	7-4	8-10	20-10	3-8	2-8
2150	84									
2200	86									
2250	88									
2300	90									

Electric Power Transmission, Continued.

Polyphase Generators, Continued.

General Electric Revolving Field Type.

The General Electric Company neither catalogue nor offer to the trade revolving armature generators ; they did make a number of them in the beginning, but they were quick to appreciate the revolving field type, and in developing that have practically abandoned the other.



1500 K. W. Revolving Field Engine Type Generator, 40 Cycles, 75 Revs. per Minute, 2300 Volts.

The electrical and mechanical features that particularly appealed to them in adopting this type of machine were :

The field revolves inside a stationary armature, and there are no exposed high tension contacts. The cast iron frame that supports the armature winding can in the larger sizes be moved parallel with the shaft, thus giving easy access to both the field and armature for inspection or repairs. By permanently connecting the frame to earth in case of a ground between it and the winding, no shock can be obtained from the frame.

The armature windings, being stationary, are free from the strain and vibration to which those of revolving armatures are subjected. The only collector

rings are those in the low potential revolving field so that all high potential connections from armature to switchboard can be completely insulated.

The armature is made of special annealed iron laminations, which have a high magnetic permeability and are japanned to prevent eddy currents. Spacing blocks are introduced to provide for good ventilation. The laminations are provided in most cases with dove-tails that fit into the armature frame, making good mechanical joints. All armature coils are wound on forms, so that they are perfectly insulated, easily interchangeable, convenient to replace, and difficult to break down.

The magnet columns are also made of special annealed iron laminations, securely fastened to a soft steel ring, which in machines of large diameter is supported by a cast iron spider.

The field coils of all large generators are composed of copper ribbon wound edgewise with paper insulation between the convolutions. One edge of the ribbon is always exposed to the air, cooling the coil by radiation.

The insulation on the high tension coils consists of materials that have the greatest possible mechanical strength compatible with the highest insulating properties. The insulation test is made with alternating current at a voltage which is never less than twice the working potential of the generator. The minimum voltage employed is 1500 applied for one minute.

Testing.—Careful insulation tests are made on the armature and field windings :

(1). Before assembly.
(2). When set up in place.
(3). After the heat run.

The standard frequencies are 25, 40 and 60 cycles for power service. In this book, however, we shall consider only those of 40 and 60 cycles, as they are best adapted to mill work, being well suited for both power and lighting.

The General Electric Company has installed a large number of 40 cycle outfits in cotton mills, believing that frequency better adapted to this class of work,—not to mention the fact that the lower frequency meant lower speeds and less cost on the generators and motors.

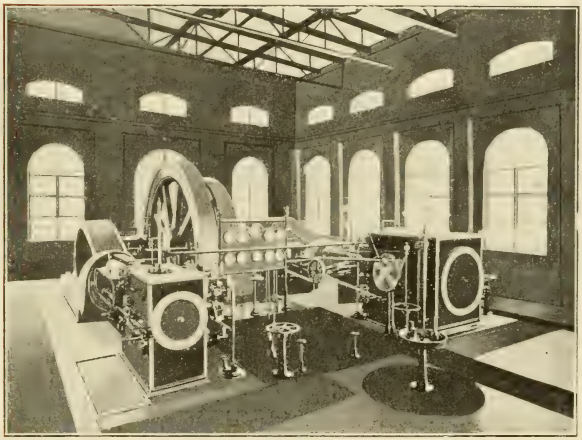
At the same time, as it is the policy of general power companies to adopt 60 cycles as their standard, it is believed that the standard cotton mill apparatus of the future will be of 60 cycles.

These machines are built for all classes of service, and of both the belt driven and direct connected types.

Electric Power Transmission, Continued.

Polyphase Generators, Continued.

G E. Revolving Field Engine Type.



G. E. Revolving Field Engine Type Generator, Direct Connected to a Cross-Compound Condensing Engine.

A model mill electric power unit, except that the high pressure cylinder takes steam from beneath the floor,—see pages 680, 683, 684 and 685.

In the evolution of the modern power station, groups of relatively small belt driven machines, occupying much floor space and incurring heavy friction losses, have been replaced by fewer and larger generators direct connected to engines or water wheels.

A general power company is compelled to install more than one unit and to proportion the sizes of the machines so as to take care of their minimum and peak (maximum) loads to the best advantage ; their power is also duplicated to avoid shut-downs as far as possible.

In mill work, however, one large unit is to be preferred to two small ones, as the load is generally uniform, and as the transmission lines are so short that trouble with them is practically out of the question.

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Engine Type, Continued.

Notes on Diagrams and Dimension Tables.

On the three following pages will be found diagrams and lettered dimension tables of Engine Type Revolving Field Alternators.

The dimensions are approximate only, and are intended simply for the convenience of engineers in laying out sketch plans and speculating upon power plant problems in a preliminary way. Of course, the space occupied by the generator is not to be added to the space required for an engine with the ordinary belt wheel; the wheels on direct connected engines being made with rims square in cross section, and the allowance for space on the shaft depending upon the width of the hub, which is greater than that of the rim of the wheel. Experience only and a general knowledge of the engine proportions will enable one to tell exactly what that would be. But, taken in connection with the tables on pages 636 to 643 inclusive, the data given, though meagre, is sufficient for an architect or an engineer familiar with such work to approximate the floor space required for direct connected units of different sizes.

The tables cover only a partial list of the machines of this type, for there is manifestly possible a practically unlimited number of sizes, as each machine of this type is specially built to suit the circumstances attending each individual case.

The kilowatt rating is based on 8% regulation at 100% power factor.

40°C. rise in temperature above surrounding air, which is taken at 25°C., at full non-inductive load, continuous operation.

25% overload for two hours without temperature rise exceeding 55°C. above surrounding air, which is taken at 25°C.

65% overload momentarily.

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Engine Type, Continued.

Table of Sizes, 40 Cycles, Separately Excited.

These machines are designed for direct coupling to engines, and are made without base, shaft or bearings.

CLASSIFICATION.						
Type.	Poles.	Kilowatt Capacity.	Speed R. P. M.	Full Load Voltage.	Maximum Field Excitation in Kws. at 125 Volts.	Bore of Spider in Inches.
ATB	48	200	100	240	12	12
ATB	48	200	100	480	12	12
ATB	24	250	200	2300	8	9
ATB	32	250	150	600	8.5	12
ATB	32	300	150	600	9	12
ATB	48	300	100	480	14	17
ATB	24	350	200	600	9.5	14
ATB	32	450	150	600	12	14
ATB	48	600	100	600	17	18
ATB	32	600	150	600	13.5	15
ATB	48	700	100	5000	18.5	24
ATB	40	750	120	600	20	20
ATB	48	900	100	600	21	22
ATB	52	900	92.5	600	23	24
ATB	40	1000	120	600	20	23
ATB	52	1250	92.5	600	26	24
ATB	64	1250	75	600	28	24
ATB	36	1300	133	600	25	20
ATB	68	1650	70.5	600	35	26
ATB	40	2000	120	600	35	26

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Engine Type, Continued.

Table of Sizes, 60 Cycles, Separately Excited.

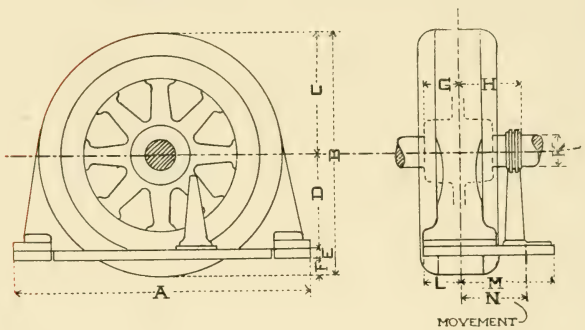
These machines are designed for direct coupling to engines, and are made without base, shaft or bearings.

CLASSIFICATION.						
Type.	Poles.	Kilowatt Capacity.	Speed R. P. M.	Full Load Voltage.	Maximum Field Excitation in Kws. at 125 Volts.	Bore of Spider in Inches.
ATB	28	125	257	240	5.5	7
ATB	28	125	257	480	5.5	7
ATB	28	125	257	2300	5.5	7
ATB	32	150	225	240	6.5	9
ATB	32	150	225	480	6.5	9
ATB	32	150	225	2300	6.5	9
ATB	32	250	225	240	8	9
ATB	32	250	225	480	8	9
ATB	32	250	225	2300	8	9
ATB	36	250	200	240	9.5	10
ATB	36	250	200	480	9.5	10
ATB	36	250	200	2300	9.5	10
ATB	48	300	150	2300	12	12
ATB	60	300	120	2300	14	15
ATB	72	300	100	2300	15	19
ATB	48	350	150	2300	13.5	15
ATB	48	400	150	2300	15	15
ATB	48	400	150	6600	11	16
ATB	72	400	100	2300	18	17
ATB	48	450	150	4150	12	16
ATB	72	450	100	480	18	17
ATB	48	500	150	2300	16	18
ATB	60	500	120	4500	19	22
ATB	80	500	90	2300	20	24
ATB	80	500	90	4000	20	24
ATB	48	600	150	2300	15.5	18
ATB	60	600	120	2300	21	18
ATB	80	600	90	600	23	20
ATB	72	800	100	2300	23	20
ATB	80	800	90	6600	24	21
ATB	48	1000	150	4150	20	17
ATB	72	1000	100	2300	28	24
ATB	72	1250	100	2300	30	18
ATB	60	1800	120	2300	30	26

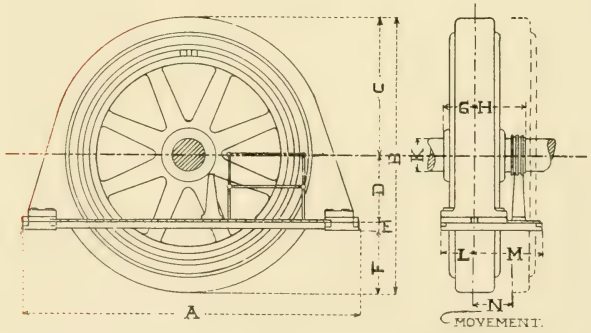
Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Engine Type, Continued.

Diagrams with Lettered Dimensions.



No. 1.



No. 2.

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Engine Type, Continued.

Table of Lettered Dimensions, ATB 40 Cycles, Separately Excited.
(In Inches.)

Poles.	K.W. Capacity.	Speed R. P.M.	Full Load Volts.	A	B	C	D	E	F	G	H	K	L	M	N	Diag. No.
48	200	100	240	159	130	65	30	6	29	9	23	12	14	37	20	2
48	200	100	480	159	130	65	30	6	29	9	23	12	14	37	20	2
24	240	200	600	104	87	43	39	5	..	7	20	9	12	36	19	1
24	250	200	2300	102	91	45	41	5	..	8	21	9	12	36	22	1
32	250	150	600	103	86	43	33	4	6	10	24	12	12	35	22	1
24	300	200	240	102	91	45	41	5	..	9	23	14	13	33	22	1
32	300	150	600	147	130	65	42	6	17	9	22	12	14	35	19	2
48	300	100	240	159	130	65	30	6	29	10	23	17	14	37	23	2
48	300	100	480	159	130	65	30	6	29	10	23	17	14	37	23	2
48	300	100	600	159	130	65	30	6	29	10	21	16	14	37	23	2
24	350	200	600	103	86	43	33	4	6	10	25	14	12	35	22	1
48	420	100	600	147	134	67	45	6	16	13	26	17	16	44	27	2
32	450	150	600	159	130	65	30	6	29	9	30	14	17	42	22	2
32	600	150	600	156	134	67	39	6	22	12	27	15	17	41	22	2
36	600	133	600	174	148	74	36	6	32	11	25	16	17	43	24	2
48	600	100	600	178	152	76	39	6	31	15	31	18	17	44	28	2
48	700	100	5000	226	186	93	34	6	53	19	36	24	20	46	26	2
40	750	120	600	189	160	80	39	8	33	19	33	20	22	51	28	2
32	900	150	600	179	148	74	39	6	29	14	29	17	20	46	27	2
48	900	100	600	226	186	93	34	6	53	19	32	22	20	46	26	2
52	900	92.5	600	240	198	99	30	6	63	20	38	24	18	42	24	2
40	1000	120	600	222	184	92	39	6	47	19	36	23	20	50	30	2
52	1250	92.5	600	240	198	99	30	6	63	20	39	24	20	48	29	2
64	1250	75	600	256	220	110	40	6	64	20	31	24	20	48	28	2
36	1300	133	600	224	186	93	37	6	50	19	32	20	20	46	28	2
68	1650	70.5	600	278	248	124	51	6	67	19	34	26	20	52	30	2
60	1800	80	600	248	220	110	51	6	53	19	34	27	20	52	32	2
40	2000	120	600	258	220	110	38	6	66	19	29	26	20	48	28	2

Note.— These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Engine Type, Continued.

Table of Lettered Dimensions, ATB 60 Cycles, Separately Excited.
(In Inches.)

Poles.	K. W. Capacity.	Speed R.P.M.	Full Load Volts.	A	B	C	D	E	F	G	H	K	L	M	N	Diag. No.
26	66	276	240	65	60	29	27	4		6	18	8	10	32	15	1
26	66	276	480	65	60	29	27	4		6	18	8	10	32	15	1
26	66	276	2300	65	60	29	27	4		6	18	8	10	32	16	1
28	100	257	240	73	66	33	27	6		7	20	10	11	31	16	1
28	100	257	480	73	66	33	27	6		7	20	10	11	31	16	1
28	100	257	2300	73	66	33	27	6		7	20	10	11	31	16	1
32	150	225	240	99	86	43	45	4		7	20	9	10	32	18	1
32	150	225	480	99	86	43	45	4		7	20	9	10	32	18	1
32	150	225	2300	99	86	43	45	4		7	20	9	10	32	18	1
48	150	150	2300	129	104	52	33	6	13	7	18	10	13	32	14	1
36	240	200	240	104	86	43	32	5	6	7	20	9	12	36	19	1
36	240	200	480	104	86	43	32	5	6	7	20	9	12	36	19	1
36	240	200	2300	104	86	43	32	5	6	7	20	9	12	36	19	1
48	250	150	4000	153	130	65	36	6	23	9	25	12	14	37	20	2
32	300	225	240	103	86	43	33	4	6	10	22	12	12	34	22	1
32	300	225	480	103	86	43	33	4	6	10	22	12	12	34	22	1
32	300	225	600	103	86	43	33	4	6	10	22	12	12	34	22	1
32	300	225	2300	103	86	43	33	4	6	10	22	12	12	34	22	1
48	300	150	2300	159	130	65	30	6	29	9	24	12	14	37	20	2
60	300	120	2300	173	150	75	39	6	30	18	29	16	13	32	19	2
72	300	100	2300	173	150	75	39	6	30	16	27	19	13	32	19	2
48	350	150	2300	159	130	65	30	6	29	10	21	15	14	37	23	2
72	360	100	6600	181	152	76	33	6	37	15	26	17	17	38	22	2
48	400	150	2300	159	130	65	30	6	29	10	25	15	14	37	20	2
60	400	120	2300	181	150	75	33	6	36	13	24	17	13	32	19	2
72	400	100	2300	181	152	76	33	6	37	15	26	17	17	38	22	2
48	400	150	6600	193	164	82	34	6	42	16	27	16	17	38	21	2
48	450	150	4150	173	150	75	39	6	30	16	27	14	13	35	21	2
72	450	100	480	181	152	76	33	6	37	15	26	17	17	38	22	2

Note.—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Engine Type, Concluded.

Table of Lettered Dimensions, Concluded.
ATB, 60 Cycles, Separately Excited.
(In Inches.)

Poles.	K. W. Capacity.	Speed R.P.M.	Full Load Volts.	A	B	C	D	E	F	G	H	K	L	M	N	Diag No.
48	500	150	6600	156	134	67	39	6	22	13	24	17	17	43	27	2
60	500	120	4500	181	152	76	33	6	37	18	29	22	17	38	22	2
80	500	90	4000	215	186	93	36	6	51	19	30	20	17	43	22	2
48	540	150	2300	156	134	67	39	6	22	13	24	17	17	43	27	2
80	540	90	2300	215	186	93	36	6	51	19	30	20	17	43	22	2
48	600	150	4000	181	152	76	33	6	37	10	25	16	17	38	23	2
60	600	120	2300	181	152	76	33	6	37	19	30	18	17	38	22	2
72	600	100	480	216	186	93	45	6	42	13	24	17	15	36	19	2
72	600	100	2300													2
80	600	90	600	215	186	93	36	6	51	19	30	20	17	43	22	2
48	750	150	2300	181	152	76	33	6	37	10	25	16	17	38	23	2
60	800	120	600	219	188	94	45	6	43	15	26	21	17	43	22	2
72	800	100	2300	224	186	93	37	6	50	19	30	20	20	46	26	2
80	800	90	4150	288	248	124	39	6	79	19	30	20	18	42	22	2
80	800	90	6600	288	248	124	39	6	79	19	30	21	18	42	22	2
48	1000	150	4150	218	186	93	42	6	45	20	31	17	20	46	26	2
72	1000	100	2300	216	186	93	45	6	42	19	30	24	22	50	30	2
60	1200	120	240	228	192	96	39	6	51	15	26	22	20	48	28	2
60	1200	120	2300	228	192	96	39	6	51	15	26	22	20	48	28	2
60	1200	120	4000	228	192	96	39	6	51	15	26	22	20	48	28	2
72	1250	100	4000	280	270	135	75	6	54	15	26	27	20	46	24	2
52	1500	138.5	4150	230	198	99	45	6	48	15	27	22	20	46	26	2
72	1500	100	2300	280	270	135	75	6	54	15	26	27	20	46	24	2
60	1800	120	2300	258	220	110	39	6	65	19	30	26	20	48	28	2
92	1800	78.5	2300	257	246	123	87	7	29	18	32	28	25	59	34	2
60	2700	120	600	248	220	110	51	6	53	19	30	30	20	52	32	2

Note.—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

Electric Power Transmission, Continued.

Polyphase Generators, Continued.

G. E. Revolving Field Belt Driven Type.

Separately Excited Machines.

These are designed with pulleys to be driven by belts or ropes, and are complete, with base, shaft, bearings, driving pulley, exciter pulley, and sliding rails. Their other mechanical and chief electrical features are practically the same as those on the preceding pages for engine type.

The following table shows the list of standard sizes :

CLASSIFICATION.						
Type.	Poles.	Kilowatt Capacity.	Speed R.P.M.	Full Load Voltage	Max. Field Excitation in Kws. at 125 V.	Number of Bearings.
40 Cycles						
ATB	8	150	600	600	3.5	2
ATB	12	300	400	600	7	3
ATB	12	300	400	2300	7	3
ATB	12	500	400	600	8	3
60 Cycles.						
ATB	8	100	900	600	2.5	2
ATB	8	100	900	2300	2.5	2
ATB	12	150	600	600	3.5	2
ATB	12	150	600	2300	3.5	2
ATB	12	150	600	5500	3.5	2
ATB	12	150	600	6600	3.5	2
ATB	12	200	600	600	4	2
ATB	12	200	600	2300	4	2
ATB	12	200	600	6600	4	2
ATB	16	250	450	6600	6.5	3
ATB	16	250	450	10000	6.5	3
ATB	16	300	450	600	7.5	3
ATB	16	300	450	1150	7.5	3
ATB	16	300	450	2300	7.5	3
ATB	20	400	360	2300	9	3
ATB	20	450	360	13200	10	3
ATB	20	500	360	2300	10	3
ATB	20	600	360	2300	11	3

60 Cycle Machines with Compensating Exciters.

The armature of the exciter is mounted on the same shaft with the revolving field, and the exciter field is furnished with the same number of poles as the alternator, the arrangement being such that both machines operate synchronously with each other.

In addition to the exciter commutator, there are two sets of collector rings and brushes arranged on the shaft as follows:

(A). One set of two rings with brushes connected to the exciter brushes for carrying continuous current to the revolving field of the alternator.

(B). One set of three rings with brushes, the rings being connected to three leads tapped from the exciter armature.

The collector rings of the exciter are connected to the secondaries of series transformers in the main circuit. These transformers serve to impress on the exciter a voltage more or less different in phase and degree from that which its fields would normally generate. The degree of reaction on the exciter voltage is different for different values and phases of the main current, and its effect can be varied by changes of the relative positions of the exciter and generator fields and also by changes of transformer ratio. The adjustments can be so made that inductive load raises the exciter voltage more than non-inductive load, the relative effects being such as to give accurate compounding for all kinds of load.

It will be noted that no compound winding is used, also that no commutator is required for rectifying the alternating current. The only accessories required outside of the regular switchboard equipment are the series transformer already mentioned, and a small rheostat which is connected in series with the exciter field.

The following table shows a list of standard sizes:

Classification.				Amperes at Full Load 2300 V.	Dimensions in Inches.			
					Floor Space.		Pulley.	
Type.	Poles.	K. W. Rating.	Speed.		Length Over All.	Width Over All.	Diam.	Face.
ATB	6	30	1200	7.5	52	56	16	7
ATB	6	50	1200	12.5	58	56	16	10
ATB	8	75	900	19	67.5	67	21	13
ATB	8	100	900	25	73.5	67	21	15
ATB	12	150	600	38	79.5	79	32	19
ATB	12	200	600	50	87	79	32	23
ATB	16	300	450	75	129	88	42	33
ATB	20	500	360	125	166	110	52	45

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Belt Driven Type, Continued.

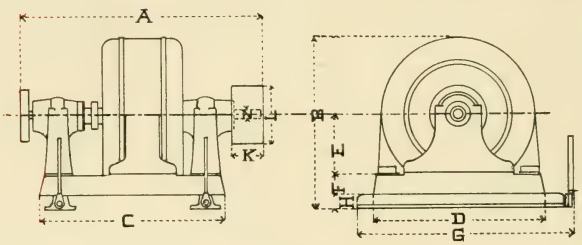


Diagram No. 1.

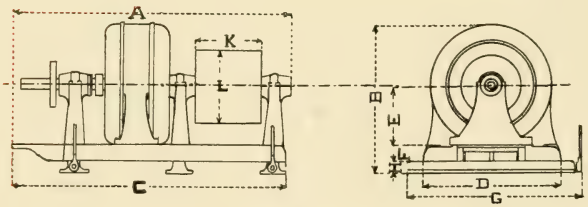


Diagram No. 2.

K. W. Rating.

Under this rating the inherent regulation of these generators will be within 8% of normal between no load and full non-inductive load under conditions of constant speed and field excitation.

The maximum rise of temperature will be 40°C. under continuous operation with full non-inductive load, or 55°C. after two hours' run with 25% overload.

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Belt Driven Type, Concluded.

Table of Lettered Dimensions, ATB Separately Excited Machines.
(In Inches.)

40 Cycles.

Poles.	K. W. Capacity.	Speed R.P.M.	Full Load Volts.	A	B	C	D	E	F	G	H	K	L	Diag. No.
6	100	800	600	84	43	58	49	15	7	73	2	19	21	1
8	150	600	600	98	64	66	63	21	8	84	7	23	32	1
8	200	600	600	104	64	67	64	21	8	84	7	28	28	1
12	300	400	600	148	85	146	78	33	10	96	7	38	48	2
12	300	400	2300	148	85	146	78	33	10	96	7	38	48	2
12	500	400	600	156	95	152	90	36	12	106	7	38	54	2

60 Cycles.

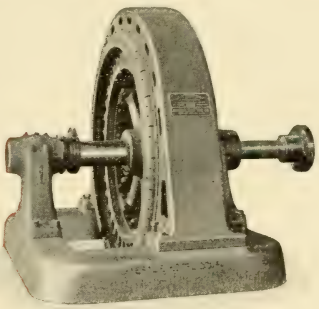
8	100	900	600	84	45	58	49	15	7	73	2	19	21	1
8	100	900	2300	84	45	58	49	15	7	73	2	19	21	1
12	150	600	600	99	64	67	64	21	8	88	7	23	32	1
12	150	600	2300	99	64	67	64	21	8	88	7	23	32	1
12	150	600	5500	99	64	67	64	21	8	88	7	23	32	1
12	150	600	6600	99	64	67	64	21	8	88	7	23	32	1
12	200	600	6600	101	64	67	64	21	8	88	7	25	32	1
12	240	600	2300	101	64	67	64	21	8	88	7	25	32	1
12	240	600	600	101	64	67	64	21	8	88	7	25	32	1
12	240	600	480	110	64	66	63	21	8	84	7	38	32	1
16	250	450	6600	159	85	157	78	33	10	96	7	38	42	2
16	250	450	10000	159	85	157	78	33	10	96	7	38	42	2
16	300	450	600	148	85	146	78	33	10	96	7	38	42	2
16	300	450	1150	148	85	146	78	33	10	96	7	38	42	2
16	300	450	2300	148	85	146	78	33	10	96	7	38	42	2
16	300	450	6600	148	85	146	78	33	10	96	7	38	42	2
20	400	360	2300	160	95	158	90	36	12	106	7	45	55	2
20	450	360	13200	188	96	186	92	36	12	106	7	50	53	2
20	500	360	600	188	96	186	92	36	12	106	7	50	53	2
20	500	360	2300	188	96	186	92	36	12	106	7	50	53	2
20	500	360	4000	188	96	186	92	36	12	106	7	50	53	2
20	600	360	2300	191	98	177	92	36	12	110	9	56	60	2
20	600	360	4150	191	98	177	92	36	12	110	9	56	53	2
24	750	300	13200	219	114	208	144	39	15	—	—	64	54	2

Note.—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

Electric Power Transmission, Continued.

Polyphase Generators, Continued.

G. E. Revolving Field Water Wheel Driven Type.



1,000 K. W. Three-Phase Revolving Field Generator.
(With Extended Shaft for Direct Connection to Water Wheel.)
ATB 36-1000-200, 2300 Volts.

These machines are designed for direct connection to water wheels or to shafts that are driven by any source of power, and are complete with base, two bearings, and shaft. The shaft is extended beyond one of the bearings for the coupling.

Their other mechanical and chief electrical features are practically the same as those on the preceding pages of the engine type.

See page 720 for a model power house equipped with this type of generator.

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Water Wheel Type, Continued.

Table of Sizes, 40 Cycles, Separately Excited.

CLASSIFICATION.					Exciter K. W. 125 Volts.	Shaft Beyond Bearing, Inches.	
Type.	Poles.	K. W. Capacity.	Speed. R. P. M.	Full Load Voltage.		Diam.	Lgth.
ATB	6	100	800	600	2.5	3	6
ATB	10	150	480	2300	3	3½	6
ATB	10	150	480	3450	3	3½	6
ATB	8	200	600	600	3	5	8
ATB	12	300	400	600	7	6	9
ATB	12	300	400	2300	7	6	9
ATB	12	300	400	5000	7.5	6	9
ATB	16	300	300	600	8	6	9
ATB	32	300	150	600	9	7	10
ATB	32	300	150	11000	10	7	10
ATB	28	400	171	600	11	7	10
ATB	32	450	150	600	12	7	10
ATB	12	500	400	5500	9	8	12
ATB	32	750	150	3450	16	10	16
ATB	40	750	120	600	20	10	16
ATB	40	750	120	12000	17	10	16
ATB	12	900	400	6600	11	7	10
ATB	32	900	150	600	18	10	16
ATB	32	900	150	2300	18	10	16
ATB	12	1000	400	600	13	7	10
ATB	20	1000	240	13200	17	9	14
ATB	32	1000	150	2300	18	9	14
ATB	32	1000	150	3450	21	9	14
ATB	16	2000	300	2300	22	12	18
ATB	20	2700	240	2300	25	12	18

Note.—See page 754 for Kilowatt rating.

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Water Wheel Type, Continued.

Table of Sizes, 60 Cycles, Separately Excited.

CLASSIFICATION.					Max. Field Excitation in K. W. at 125 V.	Shaft Beyond Bearing, Inches	
Type.	Poles.	K. W. Capacity.	Speed, R. P. M.	Full Load Voltage.		Diam.	Lgth.
ATB	16	75	450	2300	3·5	3	6
ATB	8	100	900	2300	2·5	3	6
ATB	8	100	900	600	2·5	3	6
ATB	12	100	600	2300	3	4	7
ATB	12	100	600	600	3	4	7
ATB	24	100	300	2300	4	4	7
ATB	12	150	600	2300	3·5	4	7
ATB	12	150	600	600	3·5	4	7
ATB	12	150	600	5500	3·5	4	7
ATB	12	150	600	6600	3·5	4	7
ATB	14	150	514	2300	3·5	4	7
ATB	20	150	360	230	5	5·5	8
ATB	20	150	360	600	5	5·5	8
ATB	32	150	225	2300	7	5	8
ATB	12	200	600	6600	4	5	8
ATB	14	200	514	2300	4·5	5	8
ATB	16	200	450	2300	6	5	8
ATB	12	240	600	2300	4	5	8
ATB	12	240	600	600	4	5	8
ATB	12	240	600	480	4	5	8
ATB	12	250	600	6600	6	5	8
ATB	16	250	450	6600	6·5	6	9
ATB	16	250	450	10000	6·5	6	9
ATB	28	250	257	600	8	5	8
ATB	36	250	200	2300	10	5	8
ATB	36	250	200	480	10	5	8
ATB	16	300	450	2300	7·5	6	9
ATB	16	300	450	4000	7·5	6	9
ATB	16	300	450	600	7·5	6	9
ATB	16	300	450	6600	8	6	9
ATB	18	300	400	2300	8	6	9
ATB	24	300	300	600	8	5	8
ATB	28	300	257	2300	9	5	8
ATB	32	300	225	10000	10	7	10
ATB	32	300	225	2300	9	5	8
ATB	72	300	100	2300	15	8	12

Note.—See page 754 for Kilowatt rating.

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Water Wheel Type, Continued.

Table of Sizes, 60 Cycles, Separately Excited, Concluded.

CLASSIFICATION.					Max. Field Excitation in K. W. at 125 V.	Shaft Beyond Bearing, Inches.	
Type.	Poles.	K. W. Capacity.	Speed. R. P. M.	Full Load Voltage.		Diam.	Lgth.
ATB	16	400	450	2300	8	6	9
ATB	20	400	360	480	9	5·5	8
ATB	20	400	360	2300	9	5·5	8
ATB	28	400	257	600	10	5	8
ATB	24	420	300	4400	9	5·5	8
ATB	24	420	300	6600	10	6	9
ATB	20	450	360	13200	10	5	8
ATB	24	450	300	2300	9	5·5	8
ATB	36	450	200	2300	12·5	7	10
ATB	60	450	120	600	17	8	12
ATB	20	500	360	2300	10	5	8
ATB	32	500	225	2300	12	7	10
ATB	32	500	225	600	12	7	10
ATB	32	500	225	10000	13	7	10
ATB	20	600	360	2300	11	6	9
ATB	32	600	225	2300	13	7	10
ATB	36	600	200	600	13·5	6	9
ATB	24	750	300	13200	15	8	12
ATB	40	750	180	800	17·5	10	16
ATB	40	750	180	4400	17·5	10	16
ATB	40	750	180	6600	17·5	10	16
ATB	24	800	300	2300	11·5	7	10
ATB	36	800	200	600	16	8	12
ATB	40	900	180	2300	17·5	10	16
ATB	56	900	128·5	2300	21	8	12
ATB	18	1000	400	1150	15	7	10
ATB	28	1000	257	2300	17	9	14
ATB	36	1000	200	2300	20	10	16
ATB	22	1200	327	11000	20	8	12
ATB	36	1200	200	2300	23	10	16
ATB	36	1500	200	2300	25	10	16
ATB	40	1500	180	2300	25	10	16
ATB	52	2200	138	2300	37	12	18
ATB	24	2250	300	4000	24	11	16
ATB	24	2400	300	2300	24	11	16
ATB	*40	3500	180	2300	31	12	†

*Foundation rails instead of base. †Coupling forged on end of shaft.

Note.—See page 754 for Kilowatt rating.

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Water Wheel Type, Continued.

Notes on Diagrams and Dimension Tables.

On the following five pages will be found lettered dimension tables, with diagrams to accompany the same, for G. E. Revolving Field Water-Wheel-Driven Type Generators, of both 40 and 60 cycles, and at various speeds and voltages.

The tables cover only a partial list of the machines of this type, but will no doubt be found sufficiently complete for preliminary work in most cases.

K. W. Rating.

Under this rating the inherent regulation of these generators will be within 8% of normal between no load and full non-inductive load under conditions of constant speed and field excitation.

The maximum rise of temperature will be 40°C. under continuous operation with full non-inductive load, or 55°C. after two hours' run with 25% overload.

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Water Wheel Type, Continued.

Table of Lettered Dimensions, ATB 40 Cycles, Separately Excited.
(In Inches.)

Poles.	K. W. Capacity.	Speed, R. P. M.	Full Load Volts.	A	B	C	D	E	F	N	*Diag. No.
6	100	800	2300	75	43	58	49	15	7	3	2
10	150	480	2300	76	58	55	64	21	10	5	2
10	150	480	3450	76	58	55	64	21	10	5	2
8	200	600	600	90	57	67	64	21	8	6	2
12	300	400	600	107	78	94	78	33	10	6	3
12	300	400	2300	107	78	94	78	33	10	6	3
12	300	400	5000	107	78	94	78	33	10	6	3
16	300	300	600	107	78	94	78	33	10	6	3
32	300	150	600	99	107	82	147	33	9	7	5
32	300	150	11000	99	107	82	147	33	9	7	5
28	400	171	600	99	107	82	147	33	9	7	5
32	450	150	600	110	104	93	155	27	12	7	5
12	500	400	5500	132	91	86	132	36	15	8	3
32	750	150	3450	143	128	113	176	36	18	10	5
40	750	120	600	140	134	116	186	36	18	10	5
40	750	120	12000	162	146	120	218	36	18	10	5
12	900	400	6600	145	95	128	98	39	12	8	3
32	900	150	600	143	128	113	176	36	18	10	5
32	900	150	2300	143	128	113	176	36	18	10	5
12	1000	400	600	156	93	135	92	36	15	7	3
20	1000	240	13200	147	131	122	182	36	18	9	5
32	1000	150	2300	137	128	113	176	36	18	9	5
32	1000	150	3450	145	128	119	176	36	18	10	5
16	2000	300	2300	179	131	151	148	48	12	12	6
20	2700	240	2300	179	144	151	183	48	12	12	6

Note.—All machines of 300 R. P. M. or over are provided with exciter pulleys, others are not, but in either case the dimension A is the length over all. These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purposes of installation.

*See Diagrams on pages 758-759.

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Water Wheel Type, Continued

Table of Lettered Dimensions, ATB 60 Cycles, Separately Excited.
(In Inches)

Poles.	K. W. Capacity.	Speed, R. P. M.	Full Load Volts.	A	B	C	D	E	F	N	No. *Diag.
8	100	900	2300	75	44	58	49	15	7	3	2
8	100	900	600	75	44	58	49	15	7	3	2
12	100	600	2300	63	57	36	62	29		4	1
12	100	600	600	63	57	36	62	29		4	1
24	100	300	2300	69	59	58	64	21	10	4	2
12	150	600	2300	85	57	67	64	21	8	4	2
12	150	600	600	85	57	67	64	21	8	4	2
12	150	600	5500	85	57	67	64	21	8	4	2
12	150	600	6600	85	57	07	64	21	8	4	2
14	150	514	2300	85	57	67	64	21	8	4	2
20	150	360	230	77	70	46	76	36		6	1
20	150	360	600	77	70	46	76	36		6	1
32	150	225	2300	76	77	60	80	30	10	5	2
12	200	600	6600	87	57	67	64	21	8	5	2
14	200	514	2300	87	57	67	64	21	8	5	2
16	200	450	2300	85	57	66	63	21	8	5	2
12	240	600	2300	87	57	67	64	21	8	5	2
12	240	600	600	87	57	67	64	21	8	5	2
12	240	600	480	87	57	67	64	21	8	5	2
12	250	600	6600	99	65	72	64	21	10	5	3
16	250	450	6600	117	78	105	78	33	10	6	3
16	250	450	10000	117	78	105	78	33	10	6	3
28	250	257	600	85	83	72	1000	30	10	5	5
36	250	200	2300	100	85	83	100	30	12	7	4
36	250	200	480	95	85	82	100	30	12	6	4
16	300	450	2300	107	78	95	78	33	10	6	3
16	300	450	600	107	78	95	78	33	10	6	3
16	300	450	4000	107	78	95	78	31	10	6	3
16	300	450	6600	117	78	105	78	33	10	6	3
18	300	400	2300	107	78	94	78	33	10	6	3
24	300	300	600	96	79	80	100	24	12	5	4
28	300	257	2300	85	89	74	100	36	10	5	4
32	300	225	10000	99	107	82	147	33	9	7	5
32	300	225	2300	96	85	82	100	30	12	6	4
72	300	100	2300	103	126	83	170	36	15	8	5
16	400	450	2300	107	78	94	78	33	10	6	3

Note.—All machines of 300 R. P. M. or over are provided with exciter pulleys, others are not, but in either case the dimension A is the length over all. These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purposes of installation.

*See Diagrams on pages 758-759.

Electric Power Transmission, Continued.

Polyphase Generators, G. E. Revolving Field Water Wheel Type, Continued.

Table of Lettered Dimensions, ATB 60 Cycles, Separately Excited, Concluded.

(In Inches.)

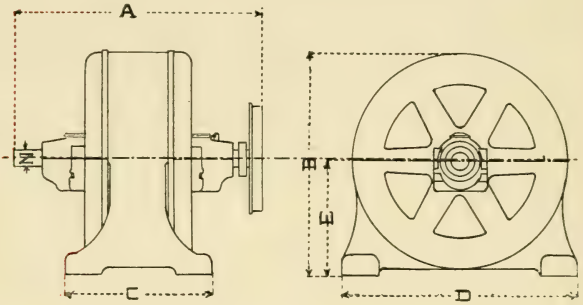
Poles.	K. W. Capacity.	Speed, R. P. M.	Full Load Volts.	A	B	C	D	E	F	N	*Diag. No.
16	75	450	2300	57	58	48	64	21	9	3	2
20	400	360	480	105	88	85	90	36	12	6	4
20	400	360	2300	104	88	93	90	36	12	6	3
28	400	257	600	95	85	82	100	30	12	5	4
24	420	300	4400	105	89	84	99	33	11	5½	4
24	420	300	6600	123	99	94	110	33	11	5½	4
24	450	300	2300	105	89	84	99	33	11	5½	4
36	450	200	2300	99	107	82	147	33	9	7	5
20	450	360	13200	122	89	111	92	36	12	5	3
60	450	120	600	102	126	83	180	36	15	8	5
20	500	360	2300	122	89	111	92	36	12	5	3
32	500	225	2300	98	110	81	149	33	12	7	5
32	500	225	600	98	110	81	149	33	12	7	5
32	500	225	10000	110	104	93	155	27	12	7	5
20	600	360	2300	114	89	95	93	36	12	6	4
32	600	225	2300	110	104	93	155	27	12	7	5
36	600	200	600	100	121	85	168	33	14	7	5
24	750	300	11500	146	105	114	144	30	15	8	5
40	750	180	800	140	134	116	186	36	18	10	5
40	750	180	4400	140	134	116	186	36	18	10	5
40	750	180	6600	140	134	116	186	36	18	10	5
24	800	300	2300	136	94	109	119	36	12	7	5
36	800	200	600								
40	900	180	2300	140	134	116	186	36	18	10	5
56	900	128.5	2300	136	142	107	203	36	16	10	5
18	1000	400	1150	156	93	135	92	36	15	7	5
28	1000	257	2300	132	121	108	154	36	15	9	5
36	1000	200	2300	134	128	108	176	36	18	10	5
22	1200	327	11000	167	109	132	154	30	18	8	5
36	1200	200	2300	139	128	113	176	36	18	10	5
36	1500	200	2300	139	128	113	176	36	18	10	5
40	1500	180	2300	147	135	119	188	36	18	10	5
52	2200	128	2300	172	159	134	240	36	18	12	5
24	2500	300	4000	172	141	147	160	54	12	11	6
24	2400	300	2300	172	141	147	160	54	12	11	6
40	3500	180	2300	192	157	180	204	54	12	9	6

Note.—All machines of 300 R. P. M. or over are provided with exciter pulleys, others are not, but in either case the dimension A is the length over all. These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

*See Diagrams on pages 758-759.

Polyphase Generators,
G. E. Revolving Field Water Wheel Type, Continued.

Diagrams to Accompany Lettered Dimension Tables.



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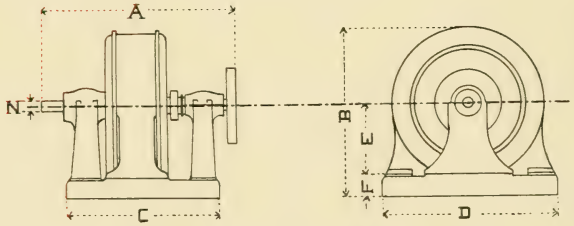

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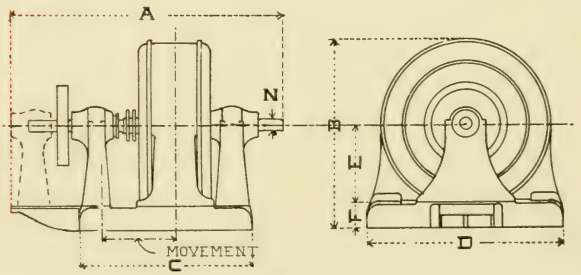
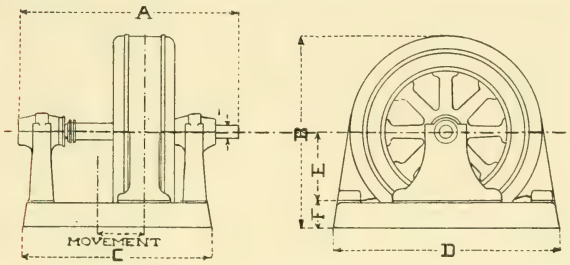


No. 3.

Electric Power Transmission, Continued.

Polyphase Generators,
G. E. Revolving Field Water Wheel Type, Concluded.



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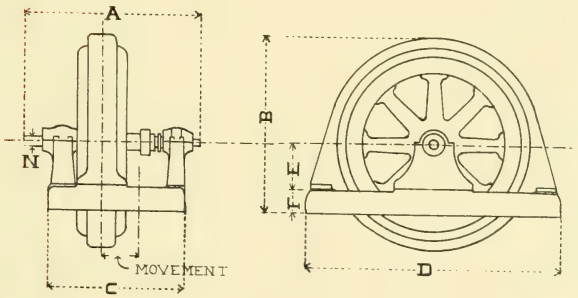

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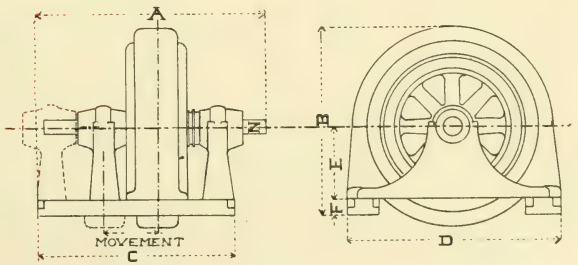


No. 6.

Electric Power Transmission, Continued.

Notes on Polyphase Generators.

The load on an alternating current generator will be either inductive or non-inductive in degree according to the devices to which current is supplied.

Incandescent lamps are non-inductive, but certain kinds of arc lamps are highly inductive, as are also induction motors and many other forms of alternating current apparatus.

When an alternating current generator is supplying current for a non-inductive load, the readings of an ammeter and voltmeter multiplied together will give the watts, which should agree with the readings of a wattmeter. With an inductive load, however, the product of the amperes and volts will be larger than the readings of the wattmeter, according to the amount of self induction in the circuit.

With a non-inductive load the wave of current coincides with the wave of the E. M. F., either alternation reversing at the same instant, but with an inductive load the wave of current lags behind the wave of the E. M. F., so that the reversal of the current does not take place until after the reversal of the E. M. F. During the time interval between the two reversals, the current therefore opposes the E. M. F. and the momentary product value of these two opposing factors produces no effect on the wattmeter. Their independent values are, however, included in the ammeter and voltmeter readings, for which reason the volt-amperes will exceed the watts in a circuit that carries an inductive load.

The difference between the total current as given by the ammeter, and the active current included in the wattmeter readings is sometimes termed the idle or wattless current because it performs no active work, nor does it entail any expenditure of energy except heating effects, or, as usually expressed, $C^2 R$ losses.

The heating effects, however, of the wattless or idle current are equivalent to those of the same amount of active current, and this is an important fact to be remembered, because where the self induction is heavy, the wattless current is correspondingly large, and the transmission lines and generators must be made proportionately larger than they would have to be with a corresponding non-inductive load running under similar conditions of temperature.

In designing alternating current generators for special use on inductive loads extra current carrying capacity is therefore often allowed, so that the machine may be run at full kilowatt output at normal temperature.

The "Power Factor" is the ratio between the readings of

Notes on Polyphase Generators, Continued.

the wattmeter and the product of the readings of the ammeter and voltmeter, *i. e.*, the ratio between the true energy watts and the volt-amperes or apparent watts.

Thus, with a load of incandescent lamps only, the watts and the volt-amperes will be the same, and the "power factor" is said to be 100%.

If some arc lamps or induction motors are now introduced into the circuit, the true watts will be less than the volt-amperes. For example, the watts may be 19000 and the volt-amperes 20000; and the power factor would then be 95%.

Briefly stated,—

$$\text{Per Cent. Power Factor} = \frac{\text{Watts}}{\text{Volt-Amperes}} \times 100.$$

The "commercial efficiency" of a generator is the ratio between the total output and the total input, and it therefore covers and includes all mechanical, electrical, and magnetic losses. For example, if a self-excited dynamo absorbs 200 H. P. or 200 K. W. at the shaft, while generating 180 K. W. at the brushes, the ratio would be 200 : 180, and the commercial efficiency would be 90%. The so-called "electrical efficiency," on the other hand, is the ratio between the output and the output plus the electrical losses only, the mechanical and magnetic losses which may be considerable and which govern the general economy of the apparatus just as much as the electrical losses, not being considered. The electrical efficiency is obviously always higher than the commercial efficiency.

If there has been a poor selection in the size of the motors, the inductive load on the generator will be such that increased generator capacity must be provided It has already been indicated, but perhaps it is well to emphasize that practically no more engine power will be required to drive this generator of greater capacity as long as the actual load remains the same. The problem affects generator capacity only.

The demonstration of the above statement is simple enough in the case of single and two-phase generators, but it becomes more complicated in the case of a three-phase machine. For instance, the reading of the three ammeters (one on each phase) times the voltage would not be the apparent capacity of a three-phase generator, but a three-phase generator can just the same be assumed to have a corresponding apparent capacity, which is its rated capacity, that will have to be proportionately increased if the generator is to work on an inductive load.

To any one desiring to know, it may be stated that the current on each phase would not be one-third the total current of the machine, as would naturally be supposed, but

Electric Power Transmission, Continued.

Notes on Polyphase Generators, Continued.

would be one-half the total current plus 16% : so that a 1,000 K. W. machine, for instance, would show not 333⅓ amperes on each phase, but would show 580 amperes at 1,000 volts.

This discrepancy in figures will be noticed by reading the instruments on the generator panel of the switchboard : for instance, the kilowatts delivered by the generator will be indicated by the wattmeter. This divided by the voltage will give a true value for the amperage delivered, which will not, however, be found to be three times the amount of current shown by the ammeter on each phase. As already stated, the ammeter on each phase will show one-half the amperage calculated from the wattmeter plus 16%, for a generator with a power factor of 100, which would be the case only for one working with a non inductive load, such as lighting. For power service these figures will vary in proportion to the resultant power factor of all the motors comprising the load.

This brief discussion is not intended to lay down a rule for calculating the results, but is intended only to make clear the peculiar conditions under which three-phase generators operate.

The E. M. F. of a generator depends upon the speed and upon the field or exciting current, but even when these are constant there is a decrease in E. M. F. as the generator is loaded, due to three causes : the resistance of the armature windings, the self-induction of the armature, and the demagnetization of the field due to the current in the armature windings. In well designed machines the resistance has a negligible effect ; the self-induction is of small consequence, and the demagnetizing effect is the principal cause of the drop in E. M. F.

This demagnetization is greater in the case of a machine furnishing current to induction motors than in one furnishing current for lighting purposes. A machine furnishing current for induction motors delivers a lagging current, the demagnetizing effect of which must be counterbalanced by increasing the current through the fields to keep the E. M. F. constant. In large machines this is usually effected by hand regulation, and in the smaller machines may be effected automatically by deriving an auxiliary direct current in the proper proportion and compounding the field with it.

It is well to bear in mind that three-phase alternators are able to deliver nearly their full capacity as single-phase machines, a very valuable feature where it is desired to operate lights on the single-phase systems.

Notes on Polyphase Generators, Continued.

It again seems well to emphasize that the term "polyphase generator" includes both two and three-phase machines, and that two and three-phase machines of the same power are exactly the same size so far as all their mechanical dimensions are concerned.

The inductor type of alternator is now practically obsolete for the drop in voltage as the load came on was excessive. It was of course out of the question to compound the field, and hand regulation was useless because the fields were practically saturated even for non-inductive loads.

High Versus Low Tension Alternators.

In the selection of apparatus, high tension machines without transformers are unhesitatingly recommended within standard voltage limitations, rather than low tension apparatus with raising transformers. Of course, this is laid down only as a general proposition. Special circumstances may dictate the opposite.

The armature of high tension alternators with revolving fields, being stationary, electrical connections between it and the switchboard appliances can be made by well insulated cables; and as there are no collector rings or brushes for high tension currents, there will be no insulated parts on the circuit. The frame of the machine is always grounded so that should the insulation of a coil by chance prove defective or get damaged, no shock could possibly be obtained from it.

All high tension switches are submerged in oil and protected by strong iron cases, conductors are heavily insulated throughout, and all terminals are located under the surface of the oil. No measuring instruments are connected directly at the high tension line, but are energized by low tension current from the secondaries of potentials and current transformers. Additional safeguards are provided by grounding the iron framework of the switchboard, the handles of the switches, and one side of each instrument circuit. It will therefore be seen that every possible precaution is taken to insure absolute immunity from dangerous shocks, so that 10,000 volt generators, for instance, and their accessory apparatus can be handled by the station attendants as safely and conveniently as 125 volt machines.

While the efficiency of a high potential generator is no greater than that of a low potential machine, there is a considerable net gain in efficiency by cutting out the losses in step-up transformers.

High tension alternators, however, are not recommended

Electric Power Transmission, Continued.

Notes on Polyphase Generators, Concluded.

for machines of small capacity.

At the present time polyphase generators are wound as high as 15,000 volts, if desired.

And finally, while a high tension machine is naturally more expensive to build than a low tension one, proper consideration must be given to the extra cost and inconvenience of the accessories that are required in connection with the latter and not with the former: such as,—

The extra cost of step-up transformers.

The electrical losses entailed by these transformers, which are often of low efficiency.

The extra cost and complication of switchboard appliances.

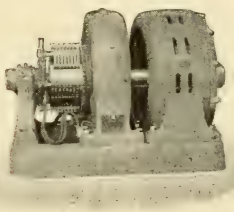
The increased liability of break-downs due to the large amount of accessory apparatus.

The additional amount of attendance required.

The extra floor space required for step-up transformers, additional switchboard panels, etc.

Exciters.

(See pages 866-881.)



Motor-Generator Set.

Duplicate exciter sets are recommended where a plant is large enough to warrant it; one of them a motor-generator set and the other either belt driven or a direct connected engine set.

The motor-generators are made up of D. C. multipolar 125 volt generators and A. C. induction motors of the proper sizes, direct connected on one base frame, and the engine type sets of D. C. 125 volt multipolar generators direct connected to automatic engines of suitable sizes.

Rule for Approximately Figuring the K W. Capacity for Exciters Used in Connection With Revolving Field Generators: Take 1% of the capacity of the generator and add to it one-fourth the number of poles; the sum will be the approximate size in kilowatts for the exciter.

Electric Power Transmission, Continued.

POLYPHASE MOTORS.

Induction Motors.

Westinghouse Types C, H and F.

Both the Type C and Type H Motors are for constant speed service, the difference being simply in the method of starting.

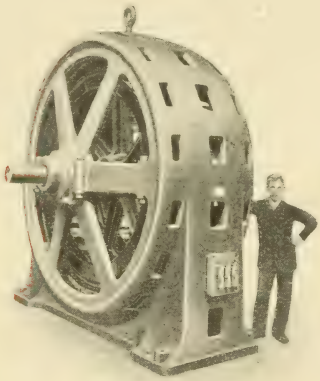
In the Type C motor the starting device is an auto-starter in the primary circuit separate from the motor which receives therefrom a reduced voltage in starting. In the Type H motor the starting device is combined with the secondary of the motor, being located on the motor shaft external to the frame. It is so arranged that a simple movement of a handle at the time of starting inserts a resistance in the path of the secondary current. As the motor accelerates, this resistance may be gradually cut out of circuit by hand until the motor is short circuited for normal running.

The Type F motor is a variable speed induction motor, especially suitable for use where loads have to be carried at reduced speeds for considerable periods of time, or where heavy loads have to be started and gradually brought up to speed. Elevator and hoist work are typical examples of this kind of service. The Type F motor differs from the Type C in the secondary or revolving element, which is wound like the rotating part of a three-phase rotating armature generator, and carries a collector. Current passes from the collector to a rheostat through a controller, by which the speed may be varied by changes in the resistance.

Electric Power Transmission, Continued.

Induction Motors, Continued.

Westinghouse Type C.



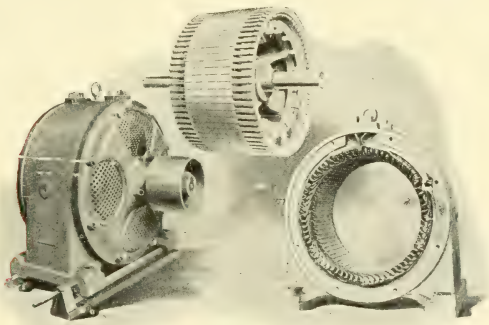
A Large Motor for Direct-Connection.

The general appearance of the motor is shown in the accompanying illustration. From a mechanical standpoint it is reduced to the simplest possible element, *i. e.*, a stationary primary, permanently connected to the main circuits, and a rotating secondary, having no electrical connection with any external circuit and having no electrical contacts or adjustments; in fact, no sliding or working friction except that of the shaft in the journals. Self-oiling bearings provide for liberal lubrication: the only attention required whatever being a moderate amount of cleaning and an occasional renewing of the oil.

The standard motors for 200 H. P. and less are provided with hollow cylindrical cast iron frames, in which the primary is mounted; in the larger sizes the cast iron frame is made in two parts, which are separated horizontally as shown in the above cut. It will be noted that the housing completely incloses the primary and secondary elements, and protects them from any external damage. The end brackets, which are a part of all motors up to 200 H. P., may be bolted to the frame in any one of eight different positions,

Induction Motors, Westinghouse Type C, Continued.

so that the oil chamber in the brackets will be in the proper position whether the frame is bolted to the floor, the wall, the ceiling, or any intermediate forty-five degree angle. Bed plates and slide rails are generally furnished only for motors to be mounted in the usual upright position, such as on the floor; when motors are fastened to the wall, or to the ceiling, or for direct connection, these are dispensed with.



Small Motor with Secondary and Primary Parts Separate to Show Their Construction.

The primary element consists of a hollow cylinder built up of laminated rings of sheet steel, slotted on the inside to receive the conductors. In motors of large sizes the rings are not continuous, but are made up of segments, dovetailed and fitted into corresponding slots in a hollow cylindrical shell of cast-iron. This shell is held in the cast-iron frame of the motor. The conductors are usually machine-wound coils of wire that are thoroughly insulated before being placed in the slots of the primary iron core. Instead of wire in some of the larger motors a copper strap, bent to the proper form, is used for the coils. In large motors wound for low voltages, in which the large current requires a large carrying capacity, a copper bar is placed in each slot; the insulated bars are slipped in at one end and the proper connections between bars are made by short lengths of copper strap. The terminal blocks, through which the leads supply the current to the motor, are connected to the primary winding and are located at the top of the motor,

Electric Power Transmission, Continued.

Induction Motors, Westinghouse Type C, Continued.

except in motors of the larger sizes, in which they are located at one side.

The Secondary is built up of laminated discs, made of a high grade of steel, mounted upon a spider, and carries the rectangular copper bars of the winding in partially closed slots around its periphery. The construction is such that the bars cannot be thrown out by centrifugal force. The conductors of the secondary are all short circuited. It is evident therefore that there can be no accidental short circuits.

The motor is capable of developing a torque several times its normal full load torque ; it is therefore not liable to be stopped by a momentary overload. Moreover, the motor is not injured when it is overloaded for a short time, or even if brought to rest for several seconds with the full current on.

The power factor of this type of motor is unusually high.

The variation of speed between no load and full load is approximately 3 per cent

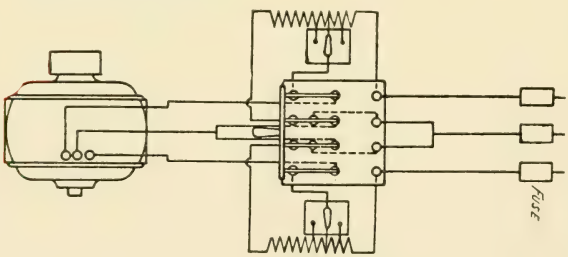


Diagram Showing Auto-Starter on Three-Phase Circuit.

Auto-Starters.—A polyphase induction motor may be started by connecting it directly to the circuit with an ordinary switch. Small motors (less than 5 H. P.) are so started in practice. The larger motors are started on a reduced voltage, the full E. M. F. of the circuit not being applied until the motors have reached their running speed. There are several methods of obtaining this low E. M. F. when starting. The auto-starter is probably the best of them, however, for it is applicable to all cases. It consists of a

Electric Power Transmission, Continued.

Induction Motors, Westinghouse Type C, Continued.

four-pole double-throw switch mounted on a cast iron box in which are two auto-transformers. When the switch is thrown in one position, the auto-transformers are connected across the circuits and deliver a low E. M. F. to the motor. When the switch is thrown in the opposite direction the auto-transformers are cut out and the motor is connected directly to the circuit. The wires from the power circuit are connected directly to the auto-starter, and the same number of wires connect the auto-starter to the motor. The auto-transformers are arranged with loops so that one of several voltages may be applied for starting, thus adjusting the starting torque to the work that the motor has to do. Thus a motor, operating a machine having great friction while starting, may be made to give a correspondingly strong starting torque, or one starting an unloaded device may be adjusted for extremely light starting torque with a corresponding reduction of current.

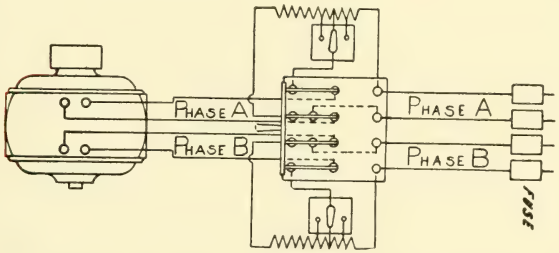


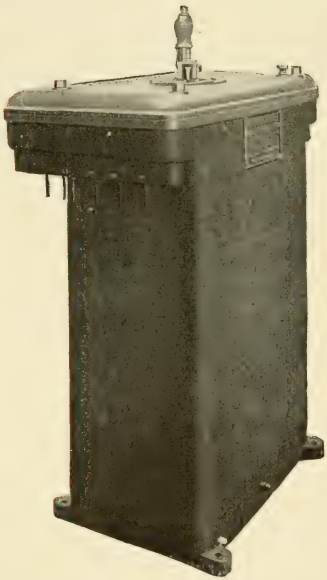
Diagram Showing Auto-Starter on Two-Phase Circuit.

The auto-starters are connected at an intermediate point when they are shipped from the factory ; if it is found that the motor starts readily, the connection may be changed to a lower point, and if it is then found that the starting torque is satisfactory, this lower point should be used, as the current taken by the motor is thereby reduced to a minimum.

On two-phase circuits in which there are four wires, different E. M. F's. exist between the different pairs of wires,

Electric Power Transmission, Continued.

Induction Motors, Westinghouse Type C, Continued.



and in some cases this affords a simple way of obtaining a low E. M. F. for starting. A simple double-throw switch is required, by which the low E. M. F. for starting is obtained by one connection, and the full E. M. F. for running is obtained by throwing the switch to the opposite direction.

When it is desirable, the starting device may be located at a convenient point more or less remote from the motor, thus entirely eliminating all danger from fire due to possible sparks. This feature is also of value when the motors are suspended from the ceiling or installed in places not easily accessible.

The latest type of auto-starters are oil immersed, the oil tank forming the lower part of the iron case, and is held in

Electric Power Transmission, Continued.

Induction Motors, Westinghouse Type C, Continued.

place by four bolts that may be readily removed for inspection of the switches. A plug is provided in the bottom of the tank for draining. The operating lever is provided with a latch for running it in the off and running positions and for stopping it at the starting position when starting the motor. Each auto-transformer is provided with five starting taps, and the starting voltages may be varied by changing the connections, which are conveniently located just inside a cover marked "starting connections". The motor leads are brought out through the case in the rear, and no live parts are exposed while the auto-starter is in operation.

The cut on the opposite page illustrates the large "controller "type for use with motors of 75 H. P. and upwards; the oil auto-starter in this case is separate from the auto-transformers. This type of auto-starter consists of two drum switches mounted vertically in a cast iron case and operated together by one lever. The auto-transformers for use with the controller have a total of ten leads each and are to be so connected as to give an increasing starting voltage on the motor as the lever is moved from the "off" to the "on" position.

Notes on Diagrams and Dimension Tables.

This type of motor is built for both two and three-phase circuits, and of any frequency desired. The tables, however, are based only upon 60 cycles (7200 alternations), as this is the frequency we recommend for mill work.

The standard voltages are 200 and 400 volts for motors up to and including 200 H. P. Motors of 20 H. P. and less are also wound for 100 volts. The standard voltage for motors larger than 200 H. P. is 400 volts. Motors of 50 H. P. and upwards may be wound for 1,000 or 2,000 volts, if specially desired.

The tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

Electric Power Transmission, Continued.

Induction Motors, Westinghouse Type C, Continued.

Motors with Two Bearings; Pulley and Slide Rails.

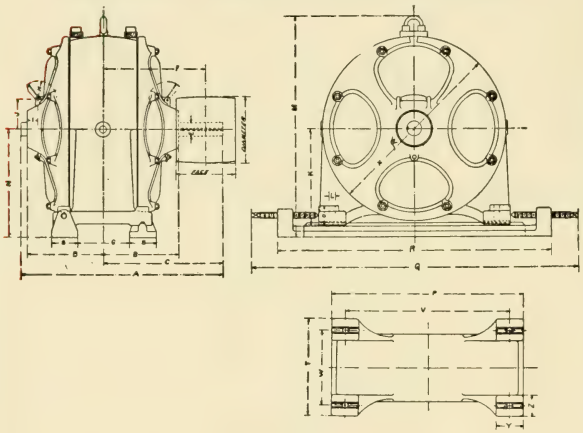


Table of Sizes.
(60 Cycles, 7200 Alternations.)

H. P.	R. P. M. Full Load.	Pulley.			Keyway.	
		Diam.	Face.	Length of Hub.	Width.	Depth in Shaft.
1	1700	5	3	2	3/16	3/32
2	1700	5	3	2	3/16	3/32
3	1700	5	4	2¾	3/8	1/8
5	1120	9	5	3½	3/8	1/8
7½	1120	9	5	4	3/8	1/8
7½	840	12	5	4	3/8	1/8
10	1120	9	5	4	3/8	1/8
10	840	14	6	4	3/8	1/8
15	1120	10	8½	5	7/16	5/32
15	840	14½	8	5	7/16	5/32
20	1120	10	8½	5	7/16	5/32
20	840	16	8	5	7/16	5/32
30	850	19	10	7	3/8	3/16
40	850	19	10	7	3/8	1/4
50	850	21	12	8	11/16	1/4

Pulleys for motors from 1 H. P. to 20 H. P., inclusive, are figured for single belt.

Pulleys for motors above 20 H. P. to 100 H. P., inclusive, are figured for light double belt.

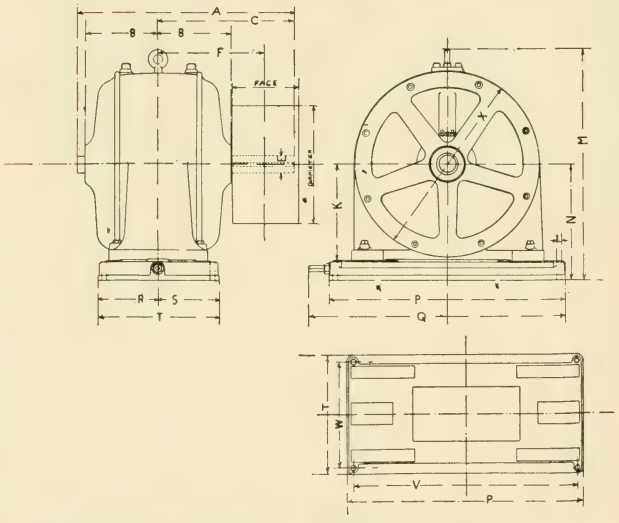
Induction Motors, Continued.

Westinghouse Type C Motors, with Two Bearings, Pulley and Slide Rails.
(Sizes and Approximate Dimensions in Inches.)
60 Cycles, 7200 Alternations.

H.P.	R.P.M. Full Load	A	B	C	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	V	W	X	Y	Z
1	1700	18 3/4	7 3/4	10 25/32	1 11/16	9 1/16	4 3/4				7	5/8	17 1/4	8 1/16	7/8	13 7/8	28 3/4	22 3/8	3	9	11 7/8	7 3/4	13 1/2	2	2 1/8
2	1700	16 3/4	6 1/4	9 5/16	1 11/16	8 1/16	5	2 7/8	3/8	1 1/2	7 1/2	1/2	18 3/8	8 9/16	3/4	15	29 1/2	23 1/2	3	9 3/4	13	8	14 1/4	2	2
3	1700	21 11/16	8 5/16	12 1/4	1 11/16	10 3/8	5	2 5/8	1 5/16	3	9 3/4	11/16	22 1/16	11 5/16	1	18 1/2	36 1/2	30 1/2	4 1/4	11 1/4	15 1/2	9 1/8	18	3	2
5	1120	24 1/2	9 1/16	13 31/32	1 15/16	12	5 1/4	2 11/16	1 3/8	3 3/8	11	3/4	26 1/16	13	2 1/4	21 3/4	39 1/4	33 3/8	4 3/4	12	18	9 1/2	20 7/8	3 1/4	2 1/2
7 1/2	1120	29 1/2	11 1/16	16 3/32	1 15/16	14 1/2	9	3 1/16	1 5/16	3 11/16	12	13/16	28 3/8	13 7/8	2 3/4	24 1/4	42 1/4	34	4 3/4	16 1/2	20 1/4	13 1/4	23	3 1/4	4 1/8
7 1/2	840	29 1/2	11 1/16	16 3/32	1 15/16	14 1/2	9	3 1/16	1 5/16	3 11/16	12	13/16	28 3/8	13 7/8	2 3/4	24 1/4	42 1/4	34	4 3/4	16 1/2	20 1/4	13 1/4	23	3 1/4	4 1/8
10	1120	29 1/2	11 1/16	16 3/32	1 15/16	14 1/2	9	3 1/16	1 5/16	3 11/16	12	13/16	28 3/8	13 7/8	2 3/4	24 1/4	42 1/4	34	4 3/4	16 1/2	20 1/4	13 1/4	23	3 1/4	4 1/8
10	840	29 1/2	11 1/16	16 3/32	1 15/16	14 1/2	9	3 1/16	1 5/16	3 11/16	12	13/16	28 3/8	13 7/8	2 3/4	24 1/4	42 1/4	34	4 3/4	16 1/2	20 1/4	13 1/4	23	3 1/4	4 1/8
15	1120	30 23/32	12 3/16	18 1/32	1 15/16	15 15/16	9 1/4	3 15/32	1 5/8	4 3/16	14 3/4	1	34	16 11/16	3 1/4	29	52	42 1/4	4 1/2	17	24 1/2	13 3/4	28	4 1/2	5 7/8
15	840	30 23/32	12 3/16	18 1/32	1 15/16	15 15/16	9 1/4	3 15/32	1 5/8	4 3/16	14 3/4	1	34	16 11/16	3 1/4	29	52	42 1/4	4 1/2	17	24 1/2	13 3/4	28	4 1/2	5 7/8
20	1120	30 23/32	12 3/16	18 1/32	1 15/16	15 15/16	9 1/4	3 15/32	1 5/8	4 3/16	14 3/4	1	34	16 11/16	3 1/4	29	52	42 1/4	4 1/2	17	24 1/2	13 3/4	28	4 1/2	5 7/8
20	840	30 23/32	12 3/16	18 1/32	1 15/16	15 15/16	9 1/4	3 15/32	1 5/8	4 3/16	14 3/4	1	34	16 11/16	3 1/4	29	52	42 1/4	4 1/2	17	24 1/2	13 3/4	28	4 1/2	5 7/8
30	850	33 21/32	13	20 29/32	2 3/8	17	8 3/4	3 11/32	2 1/4	4 3/4	16 1/4	1	37 1/4	18 3/16	3 1/4	32 1/2	55 1/2	48 1/4	4 5/8	16 1/2	27 3/4	13 1/4	31	4 1/2	5 3/4
40	850	33 21/32	13	20 29/32	2 3/8	17	8 3/4	3 11/32	2 1/4	4 3/4	16 1/4	1	37 1/4	18 3/16	3 1/4	32 1/2	55 1/2	48 1/4	4 5/8	16 1/2	27 3/4	13 1/4	31	4 1/2	5 3/4
50	850	40	14 7/16	24 1/8	2 7/8	19 7/8	10 1/2	4 1/2	2 7/16	6 1/8	19 1/8	1 1/8	44 7/16	21 5/16	3 1/4	39 1/4	62 1/4	56 1/4	4 1/2	19	33 1/4	15	37	6	4

Electric Power Transmission, Continued.

Induction Motors, Westinghouse Type C, Continued.



Motors with Two Bearings, with Pulley and Bed Plate, Sizes 75-200 H. P.

(These can also be made with extended shafts for one or two pulleys on either end or both.

Or, without pulleys and bed plate, for direct-connection, fitted with or without couplings.)

Induction Motors, Continued.

Westinghouse Type C Motor with two Bearings, Pulley and Bed Plate.

(Sizes and Approximate Dimensions in Inches.)

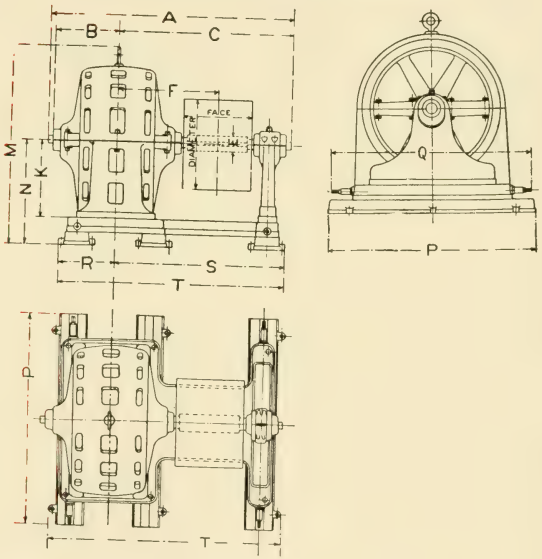
60 Cycles, 7200 Alternations.

H. P.	R. P. M. Full Load.	A	B	C	E	F	K	L	M	N	P	Q	R	S	T	V	W	X	Pulley. Diam.	Pulley. Face.	Keyway. Width	Keyway. Depth in Shaft
75	690	52½	17⅝	32⅞	3⅞	25⅝	23	1⅛	55¼	27¾	56	61	14⅝	14⅝	29¼	52¾	26	44	26	16	5/16	5/16
100	580	56	19¼	34½	4¾	27	24½	1⅛	58¾	29½	59½	64¼	15¼	15¼	30½	56¼	27¼	47¼	32	18	11/16	11/32
150	580	62½	22⅛	38	4⅞	30½	29¼	1⅛	69	34¼	70	74¾	16¼	16¼	32½	66¾	29¼	56¾	33	18	1¼	7/16
200	580	74½	25⅜	46⅞	5⅛	37	31½	1⅛	73½	36½	74	79½	18	18	36	70¾	32¾	60¼	33	24	1⅜	15/32

NOTE.—Pulleys for motors from 20 H. P. to 100 H. P., inclusive, are figured for light double belt.
Pulleys for motors from 100 H. P. to 300 H. P., inclusive, are figured for double belt.

Electric Power Transmission, Continued.

Induction Motors, Westinghouse Type C, Continued.



Motors with Three Bearings, with Pulley, Bed Plate and Slide Rails, Sizes 100-750 H. P.

This type is also made in larger sizes to special order.

These machines can be made for one or two belts as desired, or with grooved pulley for rope drive.

For direct-connection with extended shafts, machines of these sizes, like the smaller ones, are made with but two bearings.

Induction Motors, Continued.

Westinghouse Type C Motors with three Bearings, Pulley, Bed Plate and Slide Rails.

(Sizes and Approximate Dimensions in Inches.)

60 Cycles, 7200 Alternations.

H. P.	R. P. M.	A	B	C	E	F	K	M	N	P	Q	R	S	T	Pulley. Diam.	Pulley. Face.	Keyway. Width.	Keyway. Depth.
*100	580	79½	21¼	56	4⅜	31¼	24½	67	38½	84	79¾	19¾	56¼	76	32	18	1 1/16	11/32
*150	580	88	22⅛	63	4⅞	33½	29¼	79	44¾	84	83	20⅞	62⅜	83⅛	33	18	1⅜	16/32
†175	285	107½	32⅛	72¼	7	41½	40	104½	55	113	103¾	27⅛	80¼	97⅜	70	18	1¾	19/32
175	285	124½	32⅛	89¼	7	50	40	104½	55	113	103¾	27⅛	97¼	114⅜	56	24	1¾	19/32
*200	580	.. ..	25⅛	. . .	....	. . .	31½	.....	....	....	.....	....	....	.....	33	24	1⅜	15/32
300	495	114½	30⅛	81¼	6½	45½	35½	94¾	50½	98	94	25	78¾	103¾	40	28	1 1/16	17/32
400	435	124½	32⅛	89¼	7	50	40	104½	55	113	103¾	27⅛	87¼	114⅜	46	36	1¾	19/32
500	390	133½	35⅛	95⅞	7	54⅝	42	109⅜	57	113	107½	31¼	93¼	124½	55	40	1¾	19/32
750	300	177	41½	121½	10	72	63	142	80½	150½	142	35⅞	129⅜	165	69½	50¼	2¼	¾

* The frames of these machines are not split. † For Rope Drive.

NOTE.—Pulleys for motors above 100 H. P. to 300 H. P., inclusive, are figured for double belt.
Pulleys for motors above 300 H. P. are figured for triple belt.

Electric Power Transmission, Continued.

Induction Motors, Continued.

Westinghouse Type H.

The general appearance of the Type H motor is similar to that of the Type C previously illustrated and described, except that in the Type H motor the cylindrical case of the motor is on one end of the shaft extended to receive it.

The particular characteristics of the type H motor are: first, that the speed adjustments during the operation of starting are made gradually and not by sudden jumps, and, second, that the current for starting a given load is less than that taken by the Type C motor. In securing these starting characteristics it has been necessary to introduce certain features which are inferior to those of the Type C motor. Thus, simplicity of mechanical construction is sacrificed when the Type C secondary with its squirrel cage winding consisting of a number of copper bars solidly connected to heavy rings at each end, is replaced by the Type H secondary with a regular winding similar to that of a three-phase generator and furnished with terminals brought out to the resistance—all of which is obviously a much less simple and substantial construction than that employed in the Type C motor. Then again, because the starting device is placed on the motor itself, there is not the same latitude in locating the motor as is permitted by the starting device of the Type C motor. There is also a slightly reduced power factor which arises from the fact that the secondary has a polar winding instead of a cage winding.

The starting characteristics of the Type H motor make it especially adapted to those plants in which close regulation of voltage is essential, but where owing to the small size of the generators, or the large drop in the circuits and wiring, there is likely to be a drop in the voltage when a motor load is thrown upon the circuit. It is to be borne in mind also, that while the liability to disturbance is reduced by selecting a motor in which the starting current is reduced to a minimum, it is only in a particular and limited class of service, in which the supply system is limited or inadequate or in which there is some special necessity of maintaining an undisturbed voltage, that a motor like the Type H is preferable to the Type C motor.

Electric Power Transmission, Continued.

Induction Motors, Continued.

Westinghouse Type H, Concluded.

Starter.—The starter consists of a relatively high resistance, which is placed in circuit before starting, by pulling out a small cylinder within the starter This cylinder makes sliding contact with the resistance. As the motor speeds up, the cylinder is pushed in, cutting out resistance as it moves inward, until when entirely home, the resistance is cut out and the secondary is short circuited. In this movement, the resistance is cut out by what amounts to practically an infinite number of steps.

The starting resistance is enclosed in a polished steel cylinder of small size, rigidly attached to the shaft and external to the motor frame. Its removal can be quickly accomplished, in which event the leads may be short circuited and the motor may be started like a Type C motor.

The case of the starter is dust proof, and being of enclosed construction, may be used with impunity even in the presence of inflammable vapors, or dust laden air. In this respect the motor is on a par with the Type C motor—sparkless in operation.

Table of Sizes.

(60 Cycles, 7200 Alternations.)

H. P.	R. P. M. Full Load.	A.	Pulley.		These are the standard sizes; larger ones can be built if desired.
			Diam.	Face.	
5	1120	37½	9	5	
7½	1120	42¼	9	5	
7½	840	42¼	12	5	
10	1120	42¼	9	5	
10	840	42¼	14	6	
15	1120	44¾	10	8½	
15	840	44¾	14½	8	
20	1120	44¾	10	8½	
20	840	44¾	16	8	

The dimensions of Type H motors are the same as Type C except "A" given above which is longer to allow for the starter when it is pulled out.
The pulleys are for single belts.

Electric Power Transmission, Continued.

Induction Motors, Continued.

Westinghouse Type F.

The Type F motor, for variable speed, is, as already stated, especially suited for use where loads are to be carried at reduced speeds, or where very heavy loads are to be started and gradually brought up to speed.

The appearance of these motors is also similar to that of the Type C; the only noticeable difference is the extension of the shaft at one end to provide for a collector and brush holder.

The speed control is secured entirely by cutting resistance in and out of the secondary circuit of the motor. This is done by controllers placed at any distance from the motor that may be desired.

Table of Sizes.

(60 Cycles, 7200 Alternations.)

No.	Nominal H. P.	Number of Poles.	A	Pulley		
				Diam.	Face.	
98	**1**	4	23	5	3	These are standard sizes; larger ones can be made if desired,
99	**2**	4	22¾	5	3	
100	**3**	4	26	5	4	
101	**5**	6	36¾	9	5	
102	**7½**	6	40¾	9	5	
102	7½	8	40¾	12	5	
102A	**10**	6	40¼	9	5	
102A	10	8	40¼	9	5	
103	**15**	6	42¼	10	8½	
103	15	8	42¼	14½	8	
103A	**20**	6	42¼	10	8½	
103A	20	8	42¼	16	8	
104	**30**	8	47¼	19	10	
104A	**40**	8	47¼	19	10	
105	**50**	8	53¼	21	12	
106	**75**	10	65¾	26	16	
107	**100**	12	67	32	18	
108	**150**	12	73¼	33	18	
109	**200**	12	86	33	24	

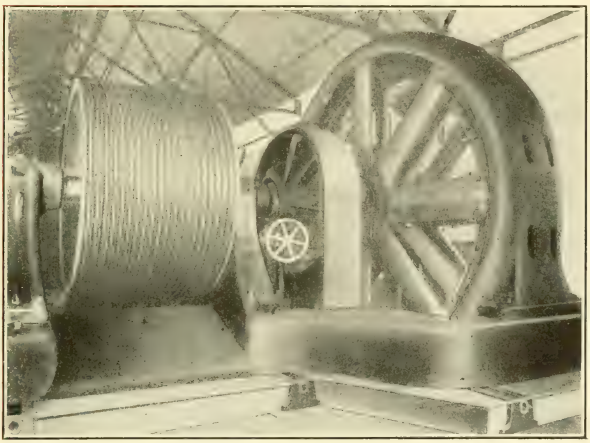
Note.—Heavy faced type indicates motors of standard sizes and speeds, which are furnished unless otherwise specified. Data is given regarding pulleys and slide rails, but these parts are not included in the standard motor equipment. Pulleys for motors from No. 98 to 103A inclusive, are figured for single belt. Pulleys for motors larger than No. 103A and in sizes up to No. 107 inclusive, are figured for light double belt. Nos. 108 and 109 are for double belt.

The dimensions of Type H motors are practically the same as Type C, except "A," given above, which is longer to allow for the extra length of shaft.

Electric Power Transmission, Continued.

Induction Motors, Continued.

General Electric Types L, K and M.



800 H. P., 180 R. P. M. Induction Motor, with Friction Clutch and Rope Sheave.

The General Electric Company manufactures three-phase and two-phase induction motors for 25, 40 and 60 cycle alternating current circuits. Three-phase motors are suitable without change for operation on monocyclic circuits through transformers.

The three types of G. E. motors are distinguished by the following characteristics: The first, known as the Form L, has a variable starting resistance inside the motor secondary or armature; the second, or Form K, has a short circuited armature and is used with a starting compensator which is connected in the motor primary or field circuit; the third, or Form M, is like the Form L, but the armature is equipped with collector rings and the resistance is external and can be cut in or out by means of a controller.

Electric Power Transmission, Continued.

G. E. Induction Motors, Continued.

Unless the starting current of an induction motor is small compared with the capacity of the feeders and generators, it is apt to seriously affect the regulation of the potential of the distributing system. Form L induction motor is, therefore, preferable when lamps and motors are to be operated from the same circuits. In power systems where close regulation is not of great importance, and the generators are of large capacity compared with the motors, Form K induction motors with compensators may be used.

When small amounts of power are required, relatively large starting currents are not objectionable. Small motors are, therefore, started by simply closing the switch. Motors of larger capacity can also be constructed so as to be started without resistance or compensators if desired.

All three-phase motors can be operated equally well from monocyclic circuits by means of two transformers. When low potential motors are supplied with power from high potential generators, transformers are also required. Two-phase motors require two transformers and three-phase motors one three-phase, or two or three single-phase transformers.

Form K motors having a double-throw line switch may be started under low voltage from taps on the secondary of transformers instead of employing compensators for this purpose. This arrangement is especially desirable on account of simplicity and cost where several motors are located close to the bank of transformers from which they are operated.

Electric Power Transmission, Continued.

G. E. Induction Motors, Continued.

Large Motors.

Large induction motors are in many cases preferable to synchronous motors since they can be operated under conditions where synchronous apparatus would have a tendency to hunt. Induction motors have a greater torque at starting, require no auxiliary equipment with exception of starting device, and consequently can be operated with less attention and less experienced attendance. They are constructed in forms K, L and M. In the larger units, however, it is desirable, even where the resistance is used only for starting, to have it separate from the motor and to use collector rings. Such motors, unless for variable speed, are furnished with a switch inside the armature so that the collector rings can be short circuited after the motor has reached normal speed. They are designated as Form LM since they combine the features of both the Form L and the Form M motors.

Two-Speed Motors.

Induction motors can be constructed for two speeds, half normal speed being obtained by changing from normal to double the number of poles. For the rotor, a short-circuited or Form K winding should be used. At half speed such a motor will have approximately half its normal capacity.

Inverted Motors.

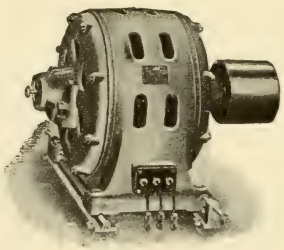
As induction motors operate in any position and require very little attention, they may be suspended from a ceiling or from a side wall and thus save valuable floor space. G. E. motors have the bearings in the end shields, and are designed for operation, bolted to the floor, wall or ceiling. Adjustment for these different positions is made by simply turning the end shields which support the bearings 90° or 180° from their original position, as the case may demand.

Electric Power Transmission, Continued.

Induction Motors, Continued.

G. E. Type L.

This motor with starting resistance in the armature is provided with a short circuiting switch placed in such a position that at starting all the resistance is included in the armature circuit. As the motor increases in speed, the resistance



A Small Type L Motor.

(Notice on the end of the shaft to the left a small handle on the end of an arm that is pushed and pulled out to vary the resistance for starting and stopping the motor. Later types of 40 H. P. and under are provided with a small lever down to the side for accomplishing this same result that is perhaps more convenient.)

may be gradually cut out by a movement of the resistance handle. By this arrangement, a large starting effort is obtained with a limited starting current. The starting resistance is of simple and rigid construction, and occupies only a small space within the armature spider. It is so designed as to give a maximum starting torque at least 50% greater than the full load running torque with about 50% above full load current. If smaller starting torque is adequate, the starting current may be proportionately reduced.

Electric Power Transmission, Continued.

Induction Motors, Continued.

G. E. Type K.

When the effect of a large starting current is not objectionable in the line, or when a motor is not required to start with full load, the induction motor with starting compensator may be used. This type of motor has the advantage of greater simplicity in construction. The armature is of the squirrel cage type, consisting simply of bare copper rods, laid in slots which contain little or no insulation. The motor may be started if desired without the usual starting compensator by simply closing the field or primary switch. It will then carry its load up to nearly synchronous speed, but with a first rush of current of six or seven times full load current. In order to cut down the starting current of this type of motor when the maximum starting torque is not required, a starting compensator is used. It is connected between the line and the motor like a transformer, reduces the potential at the terminals of the motor, and consequently diminishes its starting current. For full load torque at starting, this type of motor requires approximately four times full load running current or about four times the current required by the Form L motor under similar conditions. If, therefore, the starting current must be kept at or below full load current, the motor cannot be expected to exert more than one-quarter full load torque at starting. As soon as the motor reaches its maximum speed, the compensator should be cut out by shifting the switch handle to the running position.

Compensators are equipped with oil break switches and cartridge fuses. These fuses are connected in the line only when the starting switch of the compensator is thrown on the running position. This arrangement insures ample protection to the motor, making an additional switch and fuses for the line unnecessary.

Electric Power Transmission, Continued.

Induction Motors, Continued.

G. E. Type M.

Form M motor is generally used for cranes, hoists, elevators, etc , in preference to the Form K, for the reason that it gives a higher power factor and efficiency at reduced speeds, and particularly excels in having so much smaller losses in the motor itself. Further, its variation in speed for changes in load at lower speeds is less than that of the Form K motor. Its operation is the same as that of the Form L motor, but the rheostat, where most of the losses are concentrated, is external and therefore readily designed to remain continually in circuit, and to give any variation in speed that could be obtained from a shunt wound continuous current motor with a regulating rheostat in its armature circuit, and with the same efficiency of control.

The Form M variable speed motor with secondary control takes less current from the line at starting, for the same torque, than a motor with primary (K) control. The Form M motors will give within the limits of synchronous speed and maximum torque, any speed with any torque, depending upon the amount of resistance employed.

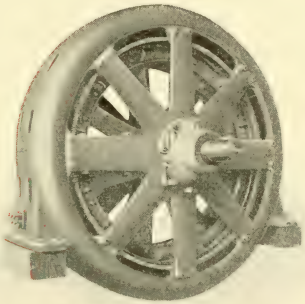
In consideration of the intermittent nature of variable speed service generally, and of the fact that the classification of the motor gives its rating on the basis of continuous operation, due allowance should be made in determining the proper motor to be used.

Induction motors for hoisting are designed to have a breaking down point of not less than three times their rated torque. Taking this into account in connection with the fact that the average hoist does not run over 10% of the time, so that there is no trouble from heating, it will be observed that in general the proper motor to use will be one the rated horse-power of which is the same as the theoretical horsepower of the work. The additional requirements to overcome friction and allow for acceleration are covered by the increase in output made possible by the intermittent service. Slow speed motors are recommended whenever induction motors are to be geared, as in hoisting. This prevents excessive gear teeth speeds with the resultant breakage of gears, and also reduces the power required to accelerate and retard the motor armature.

Outboard bearings should be used with geared motors of 15 H. P. and above.

G. E. Induction Motors, Continued.

In General.



(A large Induction Motor with extended shaft for direct coupling.)

The following table gives the standard potentials for which motors are wound:

Style Winding.	Cycles.	Volts.	
		Under 50 H. P.	50 H. P. to 150 H. P. Inclusive.
Three-phase and Two-Phase.....	60	220	440–2080
Three-phase.....	40	550	550

Within the limits of variation found under ordinary conditions, there is no serious objection to either an increased voltage or a reduced frequency, except, of course, that in the latter case the speed of the motor will be reduced in the same ratio as the frequency.

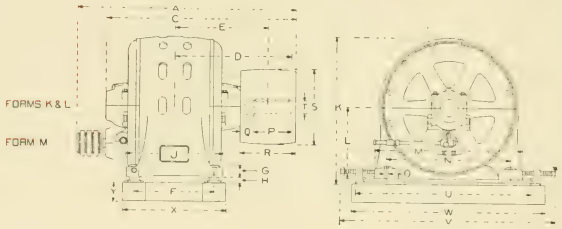
When the voltage is decreased, however, the maximum output of the motor will decrease as the square of the voltage, and when the frequency is increased, the maximum output will decrease approximately as the square root of the frequency.

The speed does not vary appreciably under load, and is not dependent upon the voltage of the system. It cannot exceed the normal if the frequency of the system remains constant.

The temperature rise by thermometer under continuous running at full load will not exceed, in either type of motor, 40°C. above the surrounding air. This moderate increase allows liberal margin for overloads without excessive heating.

Electric Power Transmission, Continued.

G. E. Induction Motors, Continued.



Diagrams.

Table of Sizes, Moderate Speeds.

Type.	40 Cycles.					60 Cycles.					T Shaft.	Keyway.
	Poles.	H. P.	Speed.	Pulley. R Face.	Pulley. S Diam.	Poles.	H. P.	Speed.	Pulley. R Face.	Pulley. S Diam.		
I	4	1	1200	2½	4½	4	1	1800	2½	4½	1 3/16	2 x ¼ x 1/8
I	4	2	1200	2½	4½	4	2	1800	2½	4½	1 3/16	2 x ¼ x 1/8
I	4	3	1200	2½	4½	4	3	1800	2½	4½	1 3/16	2 x ¼ x 1/8
I	4	5	1200	4	8	6	5	1200	4	8	1 7/16	3 ¾ x 3/8 x 1 3/16
I	4	7·5	1200	5	8	6	7·5	1200	5	8	1 7/16	3 ¾ x 3/8 x 1 3/16
I	4	10	1200	6	8	6	10	1200	6	8	1 11/16	4½ x 3/8 x 1 3/16
I	4	15	1200	7	8	6	15	1200	7	8	1 15/16	5¼ x ½ x ¼
I	6	20	800	7	14	8	20	900	7	13	2	5½ x ½ x ¼
I	6	30	800	9	14	8	30	900	9	13	2 1/16	7⅜ x ¾ x 3/8
I	6	40	800	11	14	8	40	900	11	13	3	7 x ¾ x 3/8
I	6	50	800	13	15	10	50	720	13	16	3½	8½ x ¾ x 3/8
I	6	75	800	17	15	10	75	720	17	16	4	10 x 1 x ½
I	8	100	600	17	26	12	100	600	17	26	4½	11 x 1 x ½
I	8	150	600	21	28	12	150	600	21	28	5	14 x 1 ¼ x 5/8
I	10	200	480	23	40	14	200	514	23	36	5	15 x 1 ¼ x 5/8

Note.—Use slow speed motors for gearing. Extended shaft for outboard bearing is always furnished in capacities of 15 horse-power and over.

Form L motors 40 horse-power and under are not provided with switch lever; the starting resistance being operated by a rod through end of shaft.

Induction Motors, Continued.

G. E. Moderate Speed, Forms K, L and M.
(Approximate Dimensions in Inches.)
40 Cycles, 4800 Alternations; 60 Cycles, 7200 Alternations.

H.P.	A	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	Rails.		Base Frame.		
																U	V	W	X	Y
1		18¼	10¼	9⅛	8¾	1¼	15/16	11	13 7/16	6⅜	12½	10⅜	9/16	2⅛	¼	19	23¾	20½	12¾	2
2		19½	10½	9¾	8½	1⅜	1 1/16	10¾	10 1/16	7⅜	16	13	11/16	2⅜	¼	24	27¼	25	12½	2
3		21½	11⅞	10⅜	10½	1⅜	1 1/16	12¾	16 7/16	7⅜	16	13	11/16	2¼	¼	24	27¼	25	14½	2
5	20⅜	23½	13⅝	11⅞	11	2⅛	1⅜	14	21⅞	10	22	18	13/16	3⅜	0	31	42	33½	16½	2
7.5	31⅛	20	14⅝	12⅝	13	2⅛	1⅜	16	21⅞	10	22	18	13/16	3⅜	½	31	42	33½	18½	2
10	34 1/16	28 13/16	16⅝	14½	14	2⅜	1⅝	17	25⅝	12	26	22	13/16	5 1/16	0	36	46	38½	19½	3
15	30⅜	33½	18⅝	16¼	15	2⅜	1⅝	18	25⅝	12	26	22	1/16	5⅛	0	36	46	38½	20½	3
20	41⅛	35⅜	20½	18	17½	3⅜	1½	21½	35⅝	18	37	31	1 1/16	5 1/16	1/16	44½	57	48	23½	4
30	48 1/16	42 5/16	24 11/16	21¼	19	3⅜	1½	23	35 1/16	18	37	31	1 1/16	7½	1/16	44½	57	48	25	4
40	53⅜	47⅞	27¾	23	20	3⅜	1½	24	36 1/16	18	37	31	1 1/16	7 1/16	2 1/16	44½	57	48	26	4
50	59½	51½	30½	25⅜	21	3½	1⅝	26½	43⅞	21	46	39	1⅜	8 1/16	2 1/16	60½	71	62	28	4
75	68⅝	60⅝	35½	30¼	26	3½	1⅝	31½	44⅛	21	46	39	1⅜	10 1/16	2 1/16	60½	71	62	33	4
100	68¼	60½	37¼	30¼	26	4¼	1¾	32	55	27	56	47	1 1/16	11 1/16	4 1/16	66½	81	70	34	6
150	79½	71¼	44¾	35	30	4¼	1¾	36	55⅜	27	56	47	1 1/16	15 1/16	4 1/16	66½	81	70	38	6
200	83½	75	46¾	36	30	5¾	3	39	68¼	33	68	57	2⅛	15½	6¾	84	101½	88	42	8

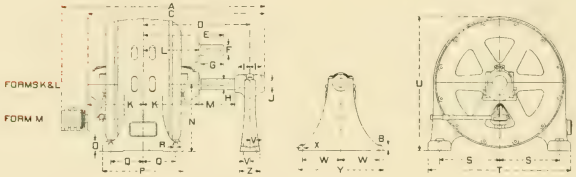
Note:—Use slow speed motors for gearing. Extended shaft for outboard bearing is always furnished in capacities of 15 H. P. and over.

Form L Motors 40 H. P. and under are not provided with switch lever; the starting resistance being operated by a rod through end of shaft.

Electric Power Transmission, Continued.

G. E. Induction Motors, Continued.

Motors with Short Shaft for Coupling and with Outboard Bearing.



Diagrams.

Table of Sizes, Slow Speeds.

Type.	40 Cycles.			60 Cycles.			Keyway.	
	Poles.	H. P.	Speed.	Poles.	H. P.	Speed.	For Short Shaft.	For Extended Shaft.
I				6	1	1200	$1\frac{11}{16}$ x $\frac{1}{4}$ x $\frac{1}{8}$	
I				6	2	1200	$1\frac{11}{16}$ x $\frac{1}{4}$ x $\frac{1}{8}$	
I	6	3	800	8	3	900	$2\frac{9}{16}$ x $\frac{1}{4}$ x $\frac{1}{8}$	
I	6	5	800	8	5	900	$2\frac{9}{16}$ x $\frac{1}{4}$ x $\frac{1}{8}$	
I	6	$7\frac{1}{2}$	800	10	$7\frac{1}{2}$	720	$2\frac{11}{16}$ x $\frac{3}{8}$ x $\frac{3}{16}$	
I	6	10	800	10	10	720	$3\frac{9}{16}$ x $\frac{3}{8}$ x $\frac{3}{16}$	
I	8	15	600	12	15	600	$3\frac{9}{16}$ x $\frac{1}{2}$ x $\frac{1}{4}$	4 x $\frac{1}{2}$ x $\frac{1}{4}$
I	8	20	600	12	20	600	$4\frac{9}{16}$ x $\frac{1}{2}$ x $\frac{1}{4}$	5 x $\frac{1}{2}$ x $\frac{1}{4}$
I	10	30	480	14	30	514	$5\frac{11}{16}$ x $\frac{3}{4}$ x $\frac{3}{8}$	$8\frac{1}{2}$ x $\frac{3}{4}$ x $\frac{3}{8}$
I	10	50	480	14	50	514	$6\frac{11}{16}$ x 1 x $\frac{1}{2}$	10 x 1 x $\frac{1}{2}$
I	12	75	400	16	75	450	$6\frac{11}{16}$ x 1 x $\frac{1}{2}$	11 x 1 x $\frac{1}{2}$
I	12	100	400	16	100	450	$7\frac{11}{16}$ x $1\frac{1}{4}$ x $\frac{5}{8}$	14 x $1\frac{1}{4}$ x $\frac{5}{8}$
I	14	150	343	20	150	360	$7\frac{11}{16}$ x $1\frac{1}{4}$ x $\frac{5}{8}$	15 x $1\frac{1}{4}$ x $\frac{5}{8}$
I	14	200	343	20	200	360	$7\frac{11}{16}$ x $1\frac{1}{4}$ x $\frac{5}{8}$	18 x $1\frac{1}{4}$ x $\frac{5}{8}$

Note.—When motors of 15 horse-power and over are to be geared, they will be supplied with extended shaft for outboard bearing.

Form L motors 40 horse-power and under are not provided with switch lever; the starting resistance being operated by a rod through end of shaft.

Induction Motors, Continued.

G. E. Slow Speed, Forms K, L and M.
(Approximate Dimensions in Inches.)
40 Cycles, 4800 Alternations; 60 Cycles, 7200 Alternations.

H.P.	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1			19 1/16		10 9/16	1	1 13/16				8 1/2	8 1/2		7 3/4	1 3/8	10 3/4	4 1/4	1 1/16	6 1/2	16	15 3/8					
2			21 1/16		11 9/16	1	1 13/16				9 1/2	9 1/2		7 1/2	1 3/8	12 3/4	5 1/4	1 1/16	6 1/2	16	15 3/8					
3	28 1/8		22 1/2		12 5/8	1 1/4	2 1/16				9 5/8	9 5/8		10	2 1/4	14	5 1/2	1 1/16	9	22	20 1/8					
5	30 1/8		24 1/4		13 5/8	1 1/4	2 1/16				10 5/8	10 5/8		10	2 1/4	16	6 1/2	1 1/16	9	22	20 1/8					
7 1/2	31 5/8		25 3/4		14 7/16	1 1/2	2 1/16				11 5/16	11 5/16		12	2 3/8	17	7	1 1/16	9	22	20 1/8					
10	35 3/4		30		17	1 3/4	3 3/16				13	13		12	2 3/8	18	7 1/2	1 1/16	11	26	24 1/8					
15	48 3/4	1 11/16	42 7/8	24 1/2	18 3/8	2	3 3/16	2 1/4	3	2	14 1/4	14 1/4	6 1/8	18	3 3/8	21 1/2	8 1/4	1 1/16	15 1/2	37	34 3/16	1 7/16	10	2 3/16	22	5 7/8
20	51 5/8	1 13/16	40	28 1/16	21 11/16	2 1/2	4 1/16	2 3/4	3 3/8	2 1/4	16 7/16	16 7/16	7 1/2	18	3 3/8	23	9 1/2	1 1/16	15 1/2	37	34 7/16	1 7/16	10 1/2	2 3/16	23 1/4	6 1/4
30	68 5/8	2 1/4	60 3/8	36	27	3 1/2	5 1/16	3 1/2	4 1/8	2 3/4	19	20 1/4	11 5/8	21	3 1/2	26 1/2	10 1/2	1 1/16	16 1/2	46	42 1/16	2 7/16	12 3/16	2 1/4	27 3/4	7 1/4
50	79	2 3/8	70 1/2	42 1/2	31 5/8	4	6 1/16	4	4 1/2	3	22 1/4	24 1/4	14 1/2	21	3 3/8	31 1/2	13	1 1/16	16 1/2	46	42 1/16	2 7/16	13 1/4	2 1/4	29	7 1/4
75	78 5/8	2 3/8	70 3/8	42 1/4	32 1/16	4 1/2	6 1/16	4 1/2	4 1/2	3	22 1/4	24 1/4	14 1/2	27	4 1/2	32	13	1 1/16	23 1/2	56	53 1/8	3	15 1/4	2 1/4	35	8 3/4
100	91	2 1/2	82 1/2	50	37	5	7 1/16	5	5 1/4	3 1/2	28 3/4	28 3/4	17 1/2	27	4 1/2	36	15	1 1/16	23 1/2	56	53 1/8	3	16 1/4	1 15/16	35 1/2	9 1/4
150	98 7/8	3	90 1/2	55	39 1/16	5	7 1/16	5	6	4	27 1/2	30 1/4	18 3/8	33	5 1/4	39	15	2	28 1/2	68	65 1/4	3 13/16	16 1/2	1 15/16	42	11 1/2
200	110 5/8	3	101 3/8	64	39 1/16	5	7 1/16	5	6	4	30 1/4	30 1/4	26 1/8	36	6 1/4	46	18	2 1/16	32	76	70 1/4	4 1/2	20 1/2	1 15/16	44	11 1/2

Note:—When motors of 15 H. P. and over are to be geared, they will be supplied with extended shaft for outboard bearing. Form L Motors 40 H. P. and under are not provided with switch lever; the starting resistance being operated by a rod through end of shaft.

Electric Power Transmission, Continued.

Notes on Induction Motors.

It will have already been noted no doubt that—
Westinghouse Type H corresponds to Gen. Elec. Form L.
Westinghouse Type C corresponds to Gen. Elec. Form K.
Westinghouse Type F corresponds to Gen. Elec. Form M.

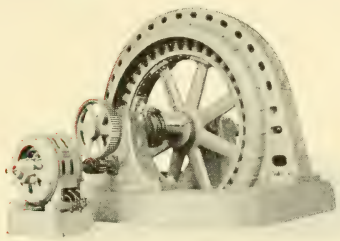
In A. C. apparatus it is necessary to discriminate carefully between the **power factor** and the **efficiency** of a motor. The product of the volts times the amperes gives only the apparent work done ; the actual work done is the product of the volts times the amperes multiplied by a percentage known as the power factor. (See page 760.) And the efficiency is the ratio of the actual mechanical power delivered to the actual electrical power received.

All induction motors take the full voltage in each phase. Single-phase motors take the full amperage in its one phase ; two-phase motors divide the amperage one-half in each phase; but three-phase motors will be found to require a little more than one-half the amperage in each phase,—the actual amount of current shown by an ammeter in each phase in a three-phase motor being found to be one-half the total current plus 16%. (See page 761 for the analogous condition existing in three-phase generators.)

Two-phase motors may be operated from two-phase generators, or through transformers from two-phase or three-phase high voltage circuits. Three phase motors may be operated from three-phase generators, or through transformers from two-phase or three-phase high voltage circuits. In each case the connection is made by a single switch connecting the motor directly to the circuit or through the auto-starter already mentioned.

Synchronous speed is the speed at which the motor will run at normal alternations where there is no "slip"; it is found by dividing the number of alternations per minute by the number of poles. This is practically the no-load speed of a motor. As the motor is loaded, however, the speed falls ; thus, the full-load speed is equivalant to synchronous speed of the motor less a certain amount of slip. For intermediate loads, or loads up to 50% above the rated load, the drop in speed or slip will be practically in proportion to the load. The amount of slip between no load and full load can be taken approximately at 3%. Tables show full-load speeds ; no-load speeds will be found somewhat higher.

SYNCHRONOUS MOTORS.



1,000 H. P. Two-Phase Revolving Field Synchronous Motor.

Any A. C. generator, either single or polyphase, may be run as a synchronous motor. Therefore tables of sizes for these motors are practically the same as those for the generators given elsewhere. The efficiency of the machines is the same whether running as generators or as motors. Their power factor is under control by adjusting the field ; they can therefore be run non-inductively without wattless current.

They require not only exciters to excite their fields, but should be started by a small induction motor ; when the synchronous motor has reached synchronous speed (or is "in step" with the generator, as it is termed), the load is thrown on by a friction clutch and the small induction starting motor is thrown out. There are a number of ways of attaching this starting motor. The one shown in the above cut is one of the most satisfactory. It will be noticed that it is simply geared to one end of the synchronous motor shaft, it being thrown out by simply disengaging its pinion from the gear on the motor shaft. The time required for a synchronous motor to get up to speed under light load is usually less than a minute.

The exciters are either direct connected to the synchronous motor shaft or driven from it by a belt.

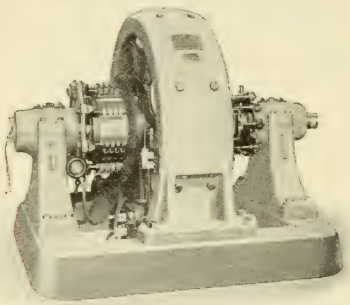
The objection to a synchronous motor is its greater cost and its elaborate and complicated type, involving the use of the exciter, the starting motor, friction clutch, and special switchboard, not to mention that more skilled attendance is required for starting and stopping.

It is true the induction motor requires more current for starting than the synchronous motor, but this objection can be done away with if it is started in the same manner as the synchronous motor. Also the larger sizes of induction motors can just as well be made in high voltages as synchronous motors.

Electric Power Transmission, Continued.

ROTARY CONVERTERS.

In some cases the distance over which power is transmitted renders the use of alternating current imperative, while direct current is desirable for the distributing circuits.



G. E. Three-Phase Rotary Converter for Converting Alternating Current into Direct Current.
Without starting motor.

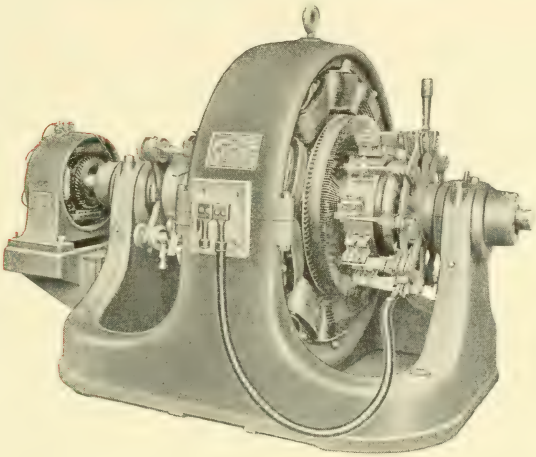
Without considering the new Hewitt Mercury Converter, which is not yet on the market and is still in the experimental stage, there are two methods available for the conversion of alternating into direct current. First, alternating current motors driving direct current generators, and, second, rotary converters in which alternating current is converted into direct current in a single armature winding.

The first method may be advantageously employed in cases where an existing direct current plant is to be operated from a power transmission circuit. It involves the installation of new alternating motors in addition to the continuous current generators, but is frequently preferred where the generators are already on hand, or it is desired to have the continuous current regulation independent of the alternating.

The second method of conversion will be readily understood by remembering that an alternator will give direct current if equipped with a commutator in addition to the collector rings. The commutator is introduced for the specific purpose of changing the alternating current into direct current. If we should tap the winding of any continuous current generator armature and supply it with alternating current of proper periodicy it would be a rotary converter.

Electric Power Transmission, Continued.

Rotary Converters, Continued.



Westinghouse 75 K. W. 60 Cycle Rotary Converter for Converting Direct Current into Alternating Current.

With starting Motor.

(This may be termed an Inverted Rotary Converter, as the standard type of machine converts alternating current into direct current.)

In appearance the rotary converter resembles a direct current multipolar generator, with the exception that collector rings are added on the side of the armature shaft opposite the commutator. The armature winding is also similar to that of the D. C. generator; this winding is tapped at certain points from which connections are carried to the collector rings, the rotary converters thus having only one winding, though connections are made from it at each end to the commutator and collector rings respectively. The field winding is also similar to the field winding of a D. C. generator and may be either shunt or compound wound.

The rotary converter can be operated in parallel with other rotary converters or with other generators; and it can be paralleled at either its supply or at its delivery end, or if necessary, at both ends simultaneously.

Methods of Starting.—The rotary converter starts under the same conditions as a synchronous motor, which it is well

Electric Power Transmission, Continued.

Rotary Converters, Continued.

known, develops a satisfactory torque only after having been brought up to normal speed. Hence, though it is possible to start the rotary converter directly from the supply circuit, this method is objectionable, inasmuch as it draws a large current of low power factor from the mains, which may affect the regulation of other apparatus on the same circuit. The method of self-starting, therefore, is only permissible when the capacity of the rotary converter is small compared to the capacity of the generator.

A second method of putting the rotary converter into operation is to start it as a direct-current motor from the commutator end, and, when it has reached synchronism, to connect it to the alternating-current mains. This method is satisfactory, but requires a supply of direct-current which may not always be available in an alternating-current station.

A third method, the most effectual one, is to start the rotary converter by means of a small induction motor, mounted upon the rotary converter shaft, and when the armature is thus brought up to synchronous speed, connection may be made to the alternating current mains. This method of starting is recommended, as the only demand on the capacity of the circuit is the small current required for the induction motor. One of the foregoing illustrations shows a starting motor mounted on the rotary converter shaft.

Flexibility of operation is a very important feature possessed by this type of machine, as it may be adapted in a variety of ways to meet particular conditions and demands.

(1). It may be supplied with alternating-current and will deliver direct current.

(2). It may be supplied with direct-current and will deliver alternating current.

(3). It may be connected to alternating-current mains and will operate as a simple synchronous motor.

(4). It may be connected to direct-current mains and will operate as a simple continuous-current motor.

(5). It may be driven as a generator by mechanical power and will deliver alternating current.

(6). It may be driven as a generator by mechanical power and will deliver direct current.

(7). It may be driven as a generator by mechanical power

Electric Power Transmission, Continued.

Rotary Converters, Concluded.

and will deliver both direct and alternating-current at the same time.

(8). It may be connected to continuous-current mains and will deliver mechanical power from a pulley on the shaft. At the same time it will deliver an alternating-current from its collector rings.

(9). It may be connected to the alternating-current mains and will deliver mechanical power from a pulley on the shaft. At the same time it will deliver a direct current from its commutator.

Notes on Rotary Converters.

The alternating voltage of a three-phase converter is about six-tenths, and of a single-phase or two-phase converter about seven-tenths, of the derived direct current voltage ; consequently step-down transformers must be employed with rotary converters, in order to supply the proper alternating voltage.

The use of the rotary converter in cotton mill work is practically limited to the motor-generator type as a duplicate exciter set. (See page 764.) At the same time, owing to the extraordinary flexibility of the operation of these machines, their use in mill work may become extended, and it therefore seems desirable to furnish at least a table of sizes of the 60 cycle (7200 alternations) machines.

Westinghouse 60 Cycle Rotary Converters, 7200 Alternations, Table of Standard Sizes.

	D. C. Voltage.		
K. W.	125	250	550
	Revolutions per Minute.		
1.87	1800		
5	1800		
7·5	1800		
37·5	1200	1200	1200
75	720	720	
100		900	900
150		720	720
200		720	720
300		514	600
400		400	450
500		360	400

Electric Power Transmission, Continued.

TRANSFORMERS.

Transformers for power transmission are of three general classes—air blast, water-cooled oil, and self-cooling oil. The air blast transformers have been especially designed for power transmissions in cases where conditions permit the banking of the transformer units in groups of large output.

They are particularly well suited for use as step-up and step-down transformers and for all substation distribution. Each bank of transformers when installed is provided with one or more blowers, by means of which a constant draft of cool air is forced through the transformers. With this method of artificial cooling, large output may be obtained without excessive cost. The power required to operate the blower is only about one-tenth of one per cent. of the aggregate output of the transformers. The employment of air blast transformers is desirable wherever it is possible to group the units so as to permit artificial ventilation.

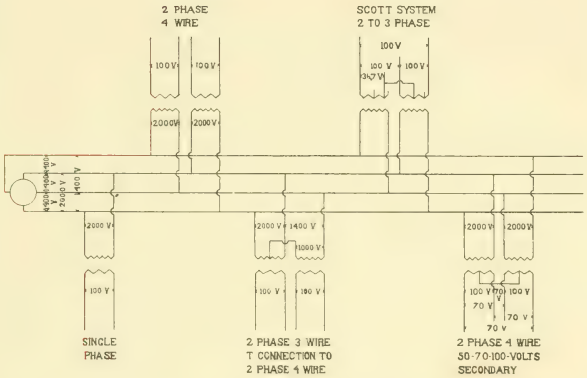
The water-cooled type is equipped with coils of pipe at the top of the tank through which cold water is passed. The oil heated by the transformer is cooled by contact with these pipes.

The air blast and water-cooled types are more economical and recommended wherever large groups of transformers are required. For small sizes and where it is not convenient to have an artificial method of cooling, the self-cooling oil type should be used.

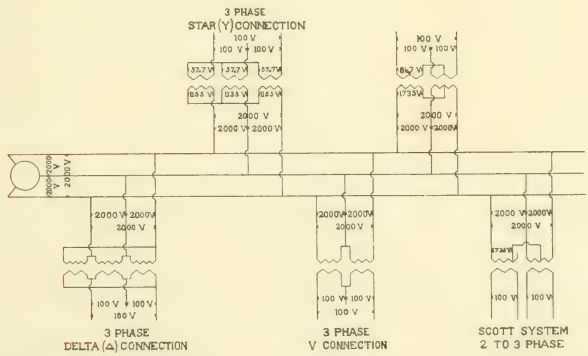
By "self-cooling" transformers is meant those which do not require air blast from fans or water circulation. This self-cooling is accomplished by ample radiating surface of the case which is corrugated and by circulating ducts for the free passage of oil through all parts of the transformer. The oil cooled type is not only desirable in itself, but the oil acts as an insulation; from lightning or other static discharges the oil frequently acts as a self-healing insulator and closes the openings made by small static sparks. The oil should be of very high fire test (over 400 degrees Fahrenheit), and free from acid, which would damage the insulation.

Electric Power Transmission, Continued.

Transformers, Continued.



Methods of Grouping Single-Phase Transformers for Polyphase Transformations. **Two-Phase 2,000 Volt Generator.**

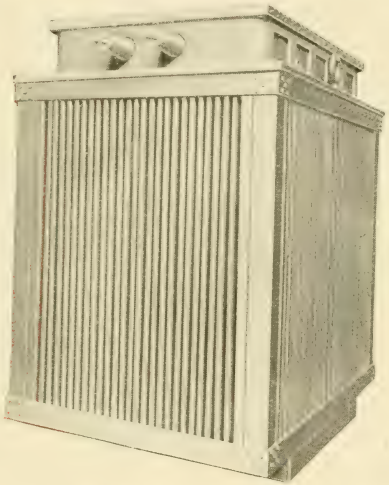


Methods of Grouping Single-Phase Transformers for Polyphase Transformations. **Three-Phase 2,000 Volt Generator.**

Electric Power Transmission, Continued.

Transformers, Continued.

Notes on Sizes and Dimensions of Self-Cooling Transformers.



Westinghouse 350 K. W. Oil Insulated Self-Cooling Transformer.

(The performance of a transformer of this size and type makes it a very efficient unit, as will be seen from the following :

Three-quarters and full load efficiency,	98%
One-half load efficiency,	97.6%
One quarter load efficiency,	96.1%
Regulation on non-inductive load,	1.4%
Regulation on load having 90% power factor,	3.3%)

Self-cooling transformers are of two general types : one with hooks for attaching to posts, and the other with flat bottoms to set on foundations in transformer houses, sub-stations, etc.

The smaller sizes for hanging on posts range from ¼ K. W. to 50 K. W. Their dimensions are evidently unimportant in mill work.

In laying out transformer houses, however, it will no doubt be a convenience to have the over all dimensions of the standard sizes. The table on the following page, therefore, gives the over all dimensions and the amount of oil contained, of sizes ranging from 10 to 500 K. W., at different voltages.

Transformers, Continued.

Table of Sizes and Dimensions, Westinghouse Self-Cooling Transformers, 60 Cycles, (7200 Alternations).

K.W.	Volts.	Gallons Oil.	Floor Space, in inches.	Height in inches.	K.W.	Volts.	Gallons Oil.	Floor Space, in inches.	Height in inches.
10	22000	60	38x23	58	150	2200	179	49x38	55
	33000	59	38x23	58		6600	175	49x38	55
	44000	57	38x23	58		11000	172	49x38	55
						16500	165	49x38	55
15	22000	59	38x23	58		22000	265	60x46	72
	33000	56	38x23	58		33000	257	60x46	72
	44000	54	38x23	58		44000	430	67x54	82
25	22000	90	39x30	60	200	2200	225	53x42	58
	33000	86	39x30	60		6600	222	53x42	58
	44000	83	39x30	60		11000	218	53x42	58
						16500	258	60x46	60
37½	22000	86	39x30	60		22000	250	60x46	72
	33000	83	39x30	60		33000	420	67x54	82
	44000	186	45x37	78		44000	410	67x54	82
50	2200	57	38x24	40	250	2200	218	53x42	58
	6600	90	39x30	48		6600	258	60x46	60
	11000	86	39x30	48		11000	265	60x46	60
	16500	83	39x30	48		16500	258	60x46	60
	22000	186	45x37	78		22000	250	60x46	72
	33000	179	45x37	78		33000	410	67x54	82
	44000	172	45x37	78		44000	400	67x54	82
75	2200	122	39x32	51	300	2200	280	60x46	60
	6600	122	39x32	51		6600	272	60x46	60
	11000	118	39x32	51		11000	400	67x54	70
	16500	114	39x32	51		16500	386	67x54	70
	2200	172	45x37	36		22000	445	67x53	82
	33000	214	51x39	74		33000	530	67x53	92
	44000	208	51x39	74		44000	515	67x54	92
100	2200	114	39x32	51	375	2200	410	67x54	70
	6600	215	39x32	51		6600	400	67x54	70
	11000	210	39x32	51		11000	560	67x54	80
	16500	193	49x38	55		16500	550	67x54	68
	22000	186	49x38	67		22000	540	67x54	92
	33000	243	53x42	70		33000	520	67x54	92
	44000	230	53x42	72		44000	545	74x56	80
125	2200	200	49x38	55	500	2200	580	67x54	80
	6600	197	49x38	55		6600	575	67x54	80
	11000	193	49x38	55		11000	565	67x54	80
	16500	186	49x38	55		16500	550	67x54	80
	22000	179	49x38	67		22000	560	74x56	80
	33000	300	60x46	72		33000	680	76x60	93
	44000	296	60x46	72		44000	670	76x60	93

Electric Power Transmission, Continued.

Transformers, Continued.

Notes on Sizes and Dimensions of Air Blast Transformers.

Westinghouse 400 K. W. Air Blast Transformer.

(The large hand hole at the bottom of the case gives easy access to the low tension terminals; the number of primary terminals at the top give different ratios of transformation.)

One blower generally supplies a number of transformers in the same station, and the transformers are usually placed above an air chamber, in which a pressure is maintained slightly above that of the surrounding air. The blower may deliver air directly into this chamber, or if it is more convenient, may be located at a distance from the transformers, feeding into a conduit which leads to the air chamber.

The blower furnished with air blast transformers is carefully selected to suit the transformer capacity. It gives a large volume of air at a low pressure, usually from ½ to 1½ oz. depending on the size of the transformer. The blower is usually direct connected to either an induction motor or a direct current motor, but it may also be driven by other means.

The table on the following page gives the over all dimensions of sizes ranging from 100 to 3000 K. W., at different voltages.

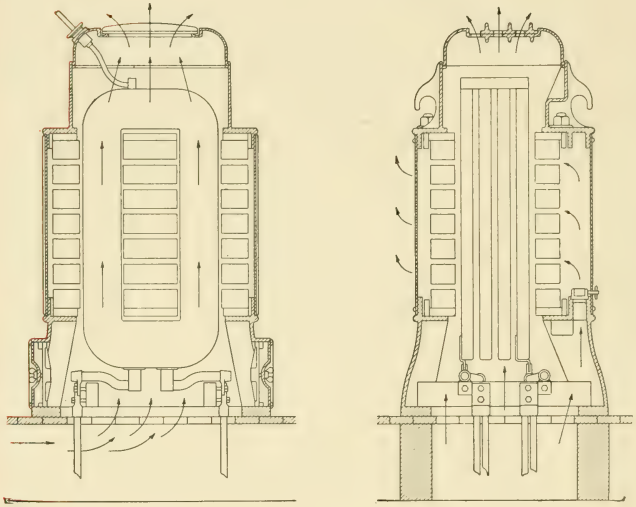
Transformers, Continued.

Table of Sizes and Dimensions, Westinghouse Air Blast Transformers, 60 Cycles, (7200 Alternations)

K. W.	Volts.	Floor Space, in inches.	Height in inches.	K. W.	Volts.	Floor Space, in inches.	Height in inches.
100	2200	52x34	27	500	2200	72x47	41
	6600	57x35	30		6600	75x47	41
	11000	60x35	30		11000	77x50	44
	16500	63x36	32		16500	81x50	44
	22000	67x36	32		22000	83x54	47
	33000	74x43	38		33000	87x57	49
125	2200	56x35	30	750	2200	79x50	44
	6600	59x35	30		6600	85x50	44
	11000	61x36	32		11000	85x54	47
	16500	65x36	32		16500	88x54	47
	22000	67x39	35		22000	89x57	49
	33000	76x43	38		33000	93x60	52
150	2200	58x35	30	1000	2200	84x54	47
	6600	59x36	32		6600	88x54	47
	11000	63x36	32		11000	88x57	49
	16500	66x39	35		16500	92x57	49
	22000	69x39	35		22000	94x60	52
	33000	76x47	41		33000	96x63	54
200	2200	59x36	32	1500	2200	88x57	49
	6600	62x36	32		6600	92x57	49
	11000	64x39	35		11000	93x60	52
	16500	69x43	38		16500	96x60	52
	22000	71x43	38		22000	97x63	54
	33000	79x47	41		33000	100x66	56
250	2200	59x39	35	2000	2200	94x60	52
	6600	63x39	35		6600	97x60	52
	11000	69x43	38		11000	97x63	54
	16500	72x43	38		16500	101x63	54
	22000	75x47	41		22000	102x66	56
	33000	81x50	44		33000	104x69	59
300	2200	65x39	35	2500	2200	97x63	54
	6600	67x43	38		6600	100x63	54
	11000	72x43	38		11000	100x66	56
	16500	74x47	41		16500	104x66	56
	22000	79x47	41		22000	106x69	59
	33000	84x50	44		33000	110x72	62
375	2200	66x43	38	3000	2200	100x66	56
	6600	70x43	38		6600	105x66	56
	11000	75x47	41		11000	107x69	59
	16500	79x47	41		16500	111x69	59
	22000	83x50	44		22000	112x72	62
	33000	85x54	47		33000	116x76	67

Electric Power Transmission, Continued.

Transformers, Continued.

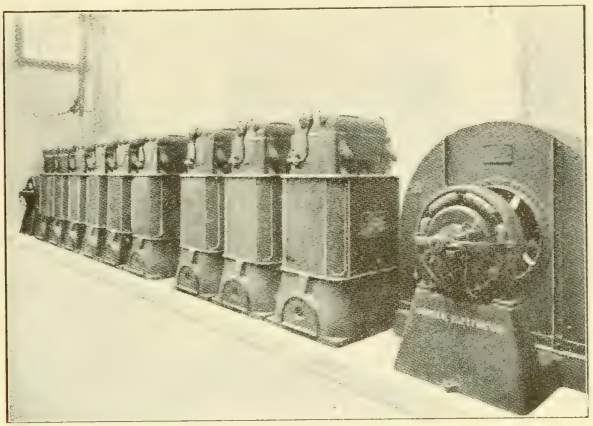


Sections showing the Construction and Air-Circulation of G. E. Air Blast Transformers.

The above cuts illustrate in a general way the system of ventilation employed in the General Electric air blast transformers. It will be seen that the air which passes through the laminations escapes at one side, and that which passes upward through the coils escapes at the top. The amount of air in each direction can be controlled by dampers.

In order that the transformers may receive the full benefit of the forced draft of air, they are usually set over a tunnel having openings at the top of proper size to be covered by the transformer base; it is good practice to make the tunnel large enough to admit a man in order that the transformers may be readily inspected and cleaned from the bottom, and it may also be very conveniently used for bringing the connecting cable to the low potential terminals, which are located in the transformer bases.

G. E. Air Blast Transformers with Motor-Driven Blower.



The following table gives different sizes of blower sets ordinarily installed by the General Electric Company:

Total K. W. of Transformers.	Size of Transformer Units, K. W.	Size of Blower.	Speed of Blower, R. P. M.	Output Blower, Cu. Ft. Per Min.	Ounce Pressure Per Sq. In.	Cu. Ft. Air Required Per Transformer Per Minute.	H. P. to Drive Blower.
900	100	50″	350	3200	.4	350	.60
1800	200	60″	325	5900	.5	600	1 10
2700	300	70″	310	8800	.6	850	2.25
4500	500	80″	310	13000	.8	1300	4.25
6750	750	90″	295	17600	.9	1800	6 75

The above figures apply to transformers of average efficiency. It will be seen that as the transformers increase in size, they require a proportionally smaller volume of air per K. W. to cool them, but it must be delivered at a higher pressure.

In case there should be a doubt at any time as to the sufficiency of ventilation supplied to a transformer, the question can be easily determined by measuring the temperature of the outgoing air with a thermometer. If the temperature is not more than 20° higher than the room temperature, the latter being normal, the ventilation may be considered all right. If the rise exceeds 20° either the ventilation is insufficient, that is, there is not enough air going through the transformer, or the transformer is overloaded.

The efficiency of a transformer being known, the necessary volume of air required may be roughly estimated by allowing 150 cubic feet per minute for every K. W. lost in the transformer.

The volume of air delivered by a blower varies directly as the speed; the pressure of the air varies as the square of the speed, and the power required to drive the blower varies approximately as the cube of the speed.

Electric Power Transmission, Continued.

Transformers, Continued.

Notes on Transformers.

For lighting circuits using small transformers, the voltage at the primaries of the step-down transformers should be made about three per cent. higher than the secondary voltage multipled by the ratio of transformation to allow for the drop in the transformers. In large transformers, this drop may be as low as 1½%.

In determining the capacity of the transformers to be used in operating motors, it is necessary to take into account the apparent efficiency of the motors as well as to allow for the drop in the transformer, which amounts to four or five per cent. The usual practice is to provide one K. W. in transformer capacity for one H. P. in motor capacity.

Transformers are preferably made for single phase. In the transformation of polyphase current two or more of these single phase transformers are connected in a group. In all cases except with two transformers on three phase the rating of the group is made equal to the sum of the ratings of the transformers comprising the group; thus, a 75 H. P. three phase motor would be provided with three single phase 25 K. W. transformers; but two transformers on three phase have a rating approximately fifteen per cent. less than the sum of the ratings of the two transformers comprising the group.

In all cases, with the exception above named, the efficiency of the group is the same as the efficiency of the transformers individually, but when two transformers are on three phase the combined or group efficiency is slightly less than the efficiencies individually.

The only occasion that is likely to arise in mill practice for the use of two transformers on a three phase circuit would be in case of the failure of one of the transformers, in which event the damaged one could be cut out and the other two would furnish practically two-thirds of the original capacity of the group, and, for that matter, for a few hours could carry the whole load. This point is brought out only that mill men may understand that the temporary breaking down of one transformer would not cause the shutting down of the section of the mill supplied by them. This advantage of being able to connect up two transformers in the case of the failure

Electric Power Transmission, Continued.

Transformers, Continued.

Notes on Transformers, Concluded.

of the third one is possible only when the transformers have their secondaries connected in Delta.

Transformers had best be proportioned to each case in hand, but it will probably be interesting to know that standard 60 cycle (7200 alternations) may be operated upon circuits of any frequency from 6,000 to 16,000 alternations.

The losses in transformers are of two kinds: 1st, the iron loss due to magnetic reversals in the iron; 2nd, copper loss resulting from the passage of current through the conductors. The higher the frequency, the less the iron loss. The copper loss is practically independent of the frequency. As a general statement, therefore, 60 cycle (7200 alternations) transformers will show a higher efficiency than those of lower frequencies.

Voltages.

Transformers may be wound for practically any voltage desired. The following high tension voltages, however, may be considered standard: 2200, 6600, 11000, 16500, 22000, 33000 and 44000. Taps are brought out from the high tension winding for three lower voltages. This provision makes it possible to use duplicate transformers at both ends of the transmission line, the taps on the lowering transformers accommodating them to the reduced line voltage. The following table shows the exact voltages for which standard Westinghouse transformers are wound:

2200	6600	11000	16500	22000	33000	44000
2100	6300	10500	15750	21000	31500	42000
2000	6000	10000	15000	20000	30000	40000
1900	5700	9500	14250	19000	28500	38000

Duplicate Blower Sets for Large Plants.

In large plants the installation of blower sets in duplicate in connection with air-blast transformers is recommended, but in case of a complete break down of the cooling apparatus, the doors on both sides of the transformer bases should be removed to permit the readiest possible access of air to the interior; with this precaution the transformer can generally be run at half load for an hour or so without any injurious effects.

Electric Power Transmission, Continued.

Transformers, Continued.

Diagrams showing Protective Devices for Low-Tension Circuits.

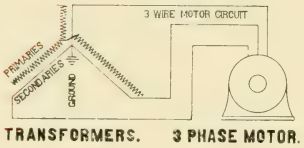


Fig. 1.

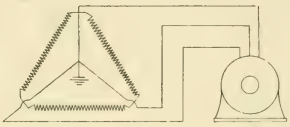


Fig. 2

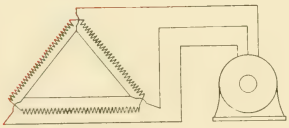


Fig. 3.

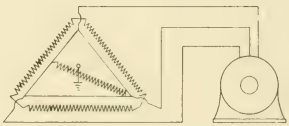
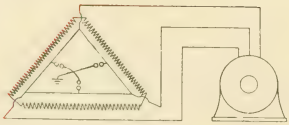


Fig. 4.



Ffg. 5.

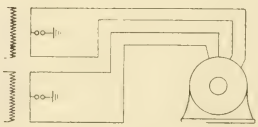


Fig. 6.

Electric Power Transmission, Continued.

Transformers, Concluded.

(Explanation of Diagrams on opposite page.)

Fig. 1.—Shows three single phase transformers with both high and low tension coils connected in star and with neutral point grounded. The strain between any low tension wire and ground is 57% of potential of low tension circuit.

Fig. 2.—Is essentially the same as Fig. 1, except that the high tension coils are connected in Delta.

These are reported to be required by the "Factory Mutual" and should one transformer of a group fail the entire system becomes inoperative.

Fig. 3.—Shows three transformers with both high and low tension coils connected in Delta and without any protective devices. Should one transformer fail it may be cut out and the system will still be operative. There is, however, no neutral point which may be grounded.

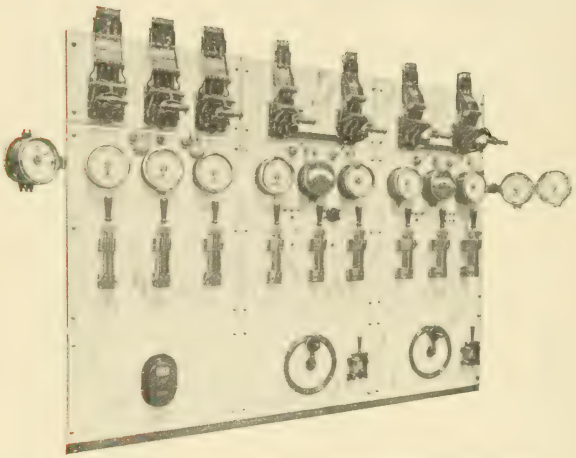
Fig. 4.—Shows the same connections as Fig. 3 but by means of a choke coil connected at proper points an artificial neutral point is made which may be grounded. This permits the system to be operated with two transformers but it will be seen that the flow of current in case of break-down of insulation is limited by the size of the auto-transformer or choke coil. If this be small probably an insufficient amount will flow to blow the protecting fuses. If the choke coil be made large it will add materially to the cost of the transformers and will make a constant additional loss in the system.

Fig. 5.—Shows transformers connected in the same way as in Fig. 3 but in addition there is a loop at the middle of each low tension coil. In each case this loop is connected to one pole of a "spark gap protector" and the other pole is grounded. The spark gap protector consists of two or more cylinders of non-arcing metal placed just far enough apart to prevent one-half the normal potential of the low tension circuit from arcing across. Should the potential in the low tension circuit rise due to surges or punctured insulations the gap will discharge and thus bring fuses or circuit-breakers into action.

Fig. 6.—Shows transformers on two phase with the same device.

Electric Power Transmission, Continued.

Switchboards and Station Equipment.



A Section of a Medium Voltage Switchboard, Comprising Two Generator Panels and one Three-Phase Feeder Panel.

(The above cut is intended simply to give a general idea of the appearance of a switchboard for three-phase generators. Two generator panels are shown on the right with double pole circuit breakers at the top of each; the third leg of the circuit in each case may be opened by its single pole jaw switch in the middle of the board. The instruments shown in order on each generator panel are an A. C. ammeter with plugs under it to each leg of the circuit, the D. C. ammeter for the fields, and the indicating wattmeter. Below these instruments are three single pole jaw switches, one for each phase, and underneath these on the lower panels are the A. C. generator rheostats and field switches. The two instruments on the bracket to the right of the switchboard are the A. C. voltmeters, one for each generator.

The panel to the left contains triple pole circuit breakers at the top for three transformers so arranged that any one may be cut out in case of damage and still permit three phases from two transformers; below this are the three A. C. ammeters and three single pole jaw switches. And on the bottom part of the panel is the integrating wattmeter. The instrument shown on the bracket to the left of the board is the synchroscope.)

The high voltages in use in modern plants have caused the most careful attention to be paid to the switchboard equipment of both the power house and the sub-stations. The effect of short circuits would not only be disastrous, but the

Switchboards and Station Equipment, Continued.

utmost precaution must be taken to insure safety in handling; the factor of safety is increased by sub-divisions in feeders, bus bars, and even of the different phases.

Marble is the proper material for high tension switchboards; slate is not suitable for voltages in excess of 600 on account of its liability to current leakages due to the presence in it of metallic veins. The instruments should be mounted on the face of the board, and the electrical connections for them made from behind. The boards are made up of separate panels, set in angle iron frames, all securely bolted together and to the adjacent wall by angle iron stays.

When step-up transformers are used, the switchboards in generating stations are divided into low and high tension equipment; the former usually includes a panel for each generator and a panel for each exciter, the high tension side consists of the necessary number of transformer and feeder panels.

For an example of a typical installation consisting of one or more generators of comparatively high voltage and a substation or transformer house at the mill, a detailed description of the switchboards of the Highland Park Manufacturing Company's power plant will be found interesting. (See chapter on Mill Engineering.) It is practically out of the question to lay down general rules for the composition of switchboards. The only guide is familiarity with the character of the work in hand, and a large experience in designing and laying it out. The immense amount of detail and complication connected with such work will be clear upon an examination of the cuts above alluded to of the switchboards, wiring plans, etc., for the Highland Park Manufacturing Company.

Without going into the details of switchboard apparatus and station equipment, which would require more space than the scope of this book will permit, there are still one or two items that should at least have a passing mention.

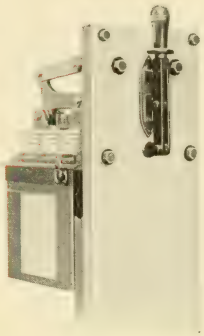
In the first place, the matter of oil switches and circuit breakers is most important. The opening of circuits of considerable current with inductive loads is not possible with the old types of switches, and so for this work they have been entirely displaced.

The term "switch" is given those pieces of apparatus in which the contacts are similar to the ordinary switch, and are opened and closed by hand.

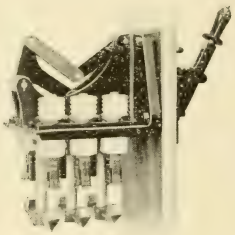
The term "circuit breaker" is given to those pieces of apparatus so designed that the contacts tend to separate and are only held in a closed position by means of triggers or toggles.

Electric Power Transmission, Continued.

Switchboards and Station Equipment, Continued.



(Opened and Closed by Hand.)



(Electrically Opened and Closed by Hand.)

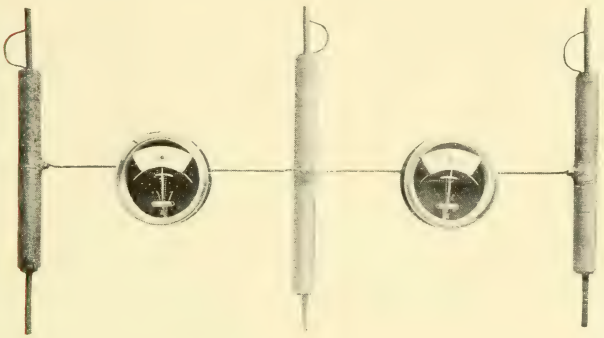
G. E. Type F, Form K, Oil Switches and Circuit Breakers.

The above type of switch has all live parts supported from a single base or frame, which constitutes the top of the switch, and the complete switch may be attached to any appropriate support as a piece of apparatus. The mechanism consists of one or more metal contact pieces, depending upon whether the switch be single, double or triple pole; each contact piece is carried upon a rod of specially treated wood. The rod or rods are connected to a cross-head which when operated by a system of levers moves in a vertical plane. The clips with which the contact pieces make connection are supported between the frame by a porcelain insulator, thoroughly insulating all live parts. The switch is closed when the contact pieces are in their upper position, and in opening the switch these contacts drop into the lower portion of the oil can. The clips, contact pieces, and all exposed live parts are completely submerged in oil when the can is in place; the can is supported from the upper frame and may be removed without taking down and disconnecting the switch. These switches are not designed to rupture loads under emergency conditions, such as a short circuit immediately beyond the switch on the load side, which can exceed 5,000 K. W. single phase or 8,500 K. W. three-phase; in excess of 4,000 K. W. single phase or 7,000 K. W. three-phase,

Switchboards and Station Equipment, Concluded.

they should not under any circumstances be mounted directly upon the switchboard, and the limits recommended are 1,500 K. W. single phase and 2,500 K. W. three-phase. For service in excess of the above conditions, single phase single pole switches should generally be used, each pole being placed in a separate fire proof compartment.

These switches correspond to the **Westinghouse Type A Oil Switches and Type B Oil Circuit Breakers.**



Westinghouse Static Ground Detectors.

This is a differential electro static voltmeter.

The instrument is connected to the circuit by means of condensers, which wholly insulate it from the line. On high voltage circuits it may with entire safety be placed on the front of a switchboard with low voltage instruments.

Each condenser consists of a tube of insulating material, on the inside and outside of which is placed a metal tube—one metal tube being connected to the meter and the other to the line wire. This form of tubular condenser offers the maximum resistance to puncture or leakage for the minimum distance between adjacent plates of the condenser. The condensers may be mounted over the line or connected into the circuit by a short length of insulated wire. In no case should the meter be placed at a greater distance than 10 feet from the condensers.

For two or three-phase circuits two ground detectors will be required.

For single and two-phase circuits two condensers are required for each meter. For three-phase circuits three condensers are required for two meters, one being of larger capacity and connected to each meter.

Electric Power Transmission, Continued.

Lightning Arresters.

(Westinghouse.)

Electrical apparatus may receive injuries of two sorts from lightning, namely, grounds and short circuits. (1) A ground or connection between the circuit and the earth is caused by the potential of the insulated portions of the apparatus rising abnormally above that of the earth and thereby rupturing the insulation. But as any properly designed piece of apparatus has sufficient insulation strength to withstand a potential considerably higher than that normally impressed upon it, to produce a ground a lightning discharge must cause a very considerable rise in the potential of the circuit. (2) Short circuits are caused by the abruptness of the static disturbances produced by lightning. The abruptness of the static wave which is the form of disturbance produced in the line by the lightning discharge, may strike a coil a blow, so to speak, that under some circumstances causes a short circuit. Electric apparatus requires, therefore, lightning protection of two sorts. First, protection against grounds; second, against short circuits. Protection from grounds is secured by means of lightning arresters; protection against short circuits, by choke coils or static interrupters. In very high tension circuits all sudden changes of static potential such as may be produced by switching, accidental grounds, or short circuits, cause the same abrupt static disturbances as lightning.

The Function of a Lightning Arrester.—The proper function of a lightning arrester is to prevent, in an insulated circuit, an abnormal rise of potential above the earth. This result is best attained by placing one or more carefully adjusted air gaps between the insulated circuit, commonly called the "line," and earth connections, or "ground." Except during times of discharge, these gaps resist any flow or current arising from the normal voltage of the line; but, whenever the line potential rises abnormally, they break down, allowing a free discharge of electricity. By careful adjustment of the gaps, an arrester can be made to discharge when the voltage of the line has risen to any predetermined value.

The Function of a Choke Coil.—The proper function of a choke coil is to prevent the short circuits sometimes caused by the local concentration of potential, such as may be produced by a lightning discharge. The choke coil, to some extent, limits an abnormal rise of potential in the apparatus by delaying the advance of a static wave from the line, and thus giving

Electric Power Transmission, Continued.

Lightning Arresters, Continued.

the arrester more time to act. As already stated, the disturbance caused by a lightning flash passes along the line in the form of a surge or "tidal wave." If this wave passes a choke coil it is flattened out and, if the coil be of sufficient power, becomes practically harmless. It is evident, however, that the choke coil receives the full force of the wave and, consequently, must be heavily insulated. Moreover, choke coils must not overheat under load, nor introduce into the circuit excessive inductive resistance. These requirements are more or less conflicting, as large choking power means many turns and the generation of much heat.

Type 7 Choke Coils.—The latest lightning arrester choke coils are designated as Type 7.

Static Interrupter.—The interrupter acts as a choke coil with magnified protective power and is used in place of Type 7 coils on very high voltage circuits. The static interrupter consists of a choke coil in series with the line and a condenser connected between the coil (on the side farthest from the line) and ground. The coil and condenser are placed in oil.

Lightning Arresters for Alternating-Current Circuits.

(Circuits not Exceeding 2500 Volts.)

Type A and Type C arresters are used on circuits of potentials not exceeding 2500 volts. These two arresters are similar in action, the Type A being intended for indoor use and the Type C for outdoor use.

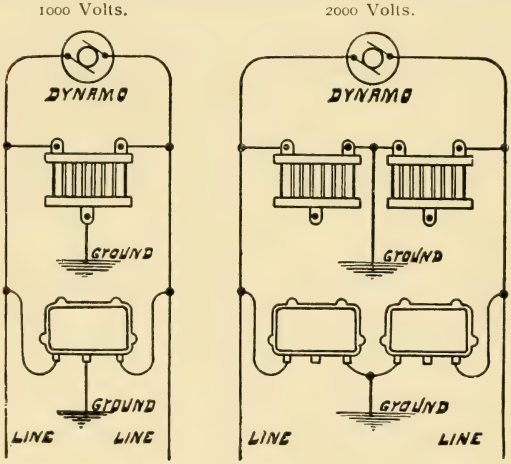
These arresters operate upon the principle, that an alternating-current cannot be maintained over a series of properly proportioned air gaps of non-arcing metal. The lightning, however, passes freely over the gaps, giving an ideal discharge path to the earth. In actual construction this arrester consists of seven independent cylinders of non-arcing metal placed side by side and separated by air-gaps. The cylinders, which are mounted on a marble base, are knurled, thus presenting many confronting points for the discharge. Leads are brought out from the first, last and middle cylinders.

When used on circuits with normal potential not exceeding 1250 volts, one Type A or Type C arrester gives protection to both sides of a 2-wire circuit, the outside leads of the arrester being connected to the line wires and the middle lead to the

Electric Power Transmission, Continued.

Lightning Arresters, Continued.

earth connection. Inasmuch as one-half of a Type A or Type C arrester is placed between each line wire and ground for 1250 volts, when an odd number of line wires is to be protected one-half of one arrester must be left idle.



Diagrams Showing Electrical Connections for A. C. Lightning Arresters.

(Not Exceeding 2500 Volts.)

When used on circuits with normal potential exceeding 1250, but not exceeding 2500 volts, the middle lead of the Type A or Type C arrester is not used, and one arrester is connected between each line wire and ground.

Low Equivalent A. C. Lightning Arresters.

(For Circuits Exceeding 2500 Volts.)

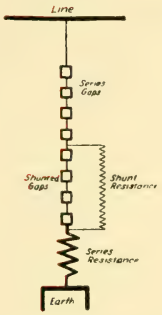
The Low Equivalent Lightning Arrester, illustrated at top of next page, consists of the following parts :

(1). Series Gaps, a number of gap units in series.
(2). Shunted Gaps and Shunt Resistance in multiple.
(3). Series Resistances.

These are connected from line to ground in the order just given.

Electric Power Transmission, Continued.

Lightning Arresters, Continued.



Gap Unit
for Low Equivalent
Arrester.

All resistances are wire-wound, and the series resistances are so wound and connected as to be nearly non-inductive.

The resistance and gap units are mounted on marble, uniform in insulating strength with that of the switchboard.

When a discharge occurs, the potential rises until the series gaps are broken down. If the discharge is sufficiently heavy, it will meet opposition in the shunt resistance and pass over the shunted gaps to earth through the series resistance. The arc which tends to follow the discharge is then withdrawn from the shunted gap, by the shunt resistance, and, aided by both resistances, is suppressed by the series gaps.

The potential at which a discharge takes place is determined by the number of series gaps—a sufficient number is used to withstand the normal voltage and yet give a proper factor of safety for the severest service. The use of the shunted gaps is to provide a by-pass for the lightning discharge, which otherwise would meet opposition in the shunt resistance The use of the shunt resistance is two-fold; first, to withdraw the arc from the shunted gaps after the passage of the discharge; second, to reduce the volume of the arc so that the series gaps, too few in number to act successfully unaided, can with this assistance suppress the arc. The small series resistance limits the initial flow of current that tends to follow the discharge, and thus prevents the burning of the cylinders.

Electric Power Transmission, Continued.

Lightning Arresters, Continued.

Instructions for Installing Lightning Arresters.

As regards the location of lightning arresters, electric plants may be divided into two groups:

(1). Plants in which the individual pieces of apparatus such as transformers, motors, arc lights, etc., are many in number and widely scattered. In these cases lightning arresters should be located for the purpose of protecting the whole line. They should be located at a number of points, more numerous on the parts of the line particularly exposed, and fewer in number on the parts that are naturally protected, especially those parts shielded by tall buildings or numerous trees. No definite statement can be made as to the number of arresters needed per mile, as the requirements of different cases vary widely. Frequently in this sort of plant, choke coils are not used on circuits not exceeding 2500 volts.

(2). Plants in which the apparatus is located at a few definite points in the system, as in a high tension transmission line. In such cases the arresters should in general be located to protect especially those points where apparatus is situated —that is, should be placed with the object of protecting the apparatus rather than the line as a whole.

The lightning arrester should always be so connected that in passing from the line to the apparatus the arrester is reached first.

On account of its nature a lightning arrester is evidently exposed to severe potential strains, consequently all live parts must be well insulated. On arresters for low voltages it is not a difficult matter to secure proper insulation, as the construction of the arrester itself affords protection. On high tension arresters, however, proper insulation is a more difficult matter. All low equivalent arresters are marble mounted, the marble being partial insulation for the arrester. On circuits exceeding 5700 volts, to obtain further insulation, the panels should be mounted on wooden supports, well dried and shellaced. For 18,000 volts and above, the panels should receive additional insulation from porcelain or glass insulators used as supports. Such insulators are furnished with the arresters. It should be considered in determining proper mounting that all parts of the resistance except the grounded end of the series resistance may be momentarily

Electric Power Transmission, Continued.

Lightning Arresters, Concluded.

at line potential during the discharge.

Two high tension arresters attached to different line wires should not be placed side by side without either a barrier or a considerable space between them.

Too much importance cannot be attached to the making of proper connections—short and straight as possible from the arrester to ground.

It is obvious that a poor ground connection will render ineffective every effort to drive static electricity into the earth. It is important, therefore, not only to construct a good ground connection, but also to appreciate thoroughly the necessity of avoiding unfavorable natural conditions.

Good ground connection for a bank of station arresters may be made in the following manner: First, dig a hole four feet square directly under the arrester until permanently damp earth has been reached; second, cover the bottom of this hole with crushed charcoal (about pea size); third, over this lay ten square feet of tinned copper plate; fourth, solder the ground wire, preferably No. 0 copper, securely across the entire surface of the ground plate; fifth, cover the ground plate with crushed charcoal, and, sixth, fill the hole with earth, using running water to settle.

The above method of making a ground connection is simple, has been found to give excellent results, and yet, if not made in proper soil, will prove of little value. Where a mountain stream is conveniently near, it is not uncommon to throw the ground plate into the bed of the stream. This, however, makes a poor ground connection, owing to the high resistance of pure water and the rocky bottom of the stream. Clay, even when wet, rock, sand, gravel, dry earth and pure water are not suitable materials in which to bury the ground plate of a bank of lightning arresters. Rich soil is best. Where permanent dampness cannot be reached, it is recommended that water be supplied to the ground through a pipe from some convenient source.

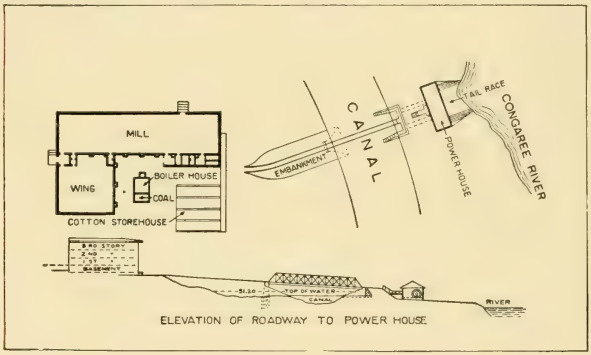
Where possible a direct connection to an underground pipe system, especially to a town or city water-main, furnishes an excellent ground, on account of the great surface contact with the earth and the numerous alternative paths for the discharge. In a water-power plant the ground should always include a connection to the pipe line or penstock.

As the effectiveness of the arrester is of great importance it should be inspected from time to time and the resistance and earth connection tested for open circuit.

Electric Power Transmission, Continued.

NOTABLE EXAMPLES.

It has been about ten years since the installation of the electric drive in the Columbia Mills, at Columbia, S. C.; its success has been complete from the very beginning. The local conditions were ideal for a typical drive of this kind. The following description by Mr. Sydney B. Paine, of the General Electric Company, will be found interesting:



ELEVATION OF ROADWAY TO POWER HOUSE

"The above cut shows a ground plan and cross section of the Columbia Mills, Columbia, S. C. This was the first textile mill in the world to be equipped throughout with the electric drive. If you examine the diagram, you will notice that there is no mill site between the river and the canal; also that the land on the river side of the canal was so low as to be very nearly covered at time of freshets. Consequently the only suitable place for the mill was on the other side of the canal. When the matter was first brought to my attention, the engineers were considering two alternatives. One was to place the wheels beneath the mill and carry the tail race through very expensive masonry beneath the canal. The other alternative was to place the wheel house between the canal and the river, and operate the mill by means of a rope drive across the canal. The advantage of the electric drive immediately appealed to them, although

they fully understood that this system had never been put into practical operation, and they decided to put the mill back from the canal on the top of the hill, and drive it electrically. It was not without some misgivings that they made this decision, but the results have abundantly justified the action of the engineers."

"This has always been a favorite picture with me, not only on account of its merits as such, but also because I consider the mill a monument to the courage and enterprise of the two men who are responsible for it,—Mr. C. K. Oliver, Treasurer, and Mr. Stephen Greene, Engineer."

Since this first installation, the arguments for and against the electric transmission of power for cotton mills have been threshed over a number of times. The general conclusion is decidedly favorable, but conservative mill men are loath to accept all the claims that have been made for it,—alleging the inability of those connected directly or indirectly with the manufacture and sale of electrical apparatus to make an impartial summation of the situation. Even the enthusiasm of a few over-sanguine mill men and one or two over-zealous mill engineers, has been discounted with actual detriment to the real value of the proposition.

In discussing the subject, I have borne in mind the fact that my own position is that not only of an engineer but of a contractor. Realizing, therefore, that mill men generally would be interested rather more in the opinions of an

Electric Power Transmission, Continued.

independent mill architect and engineer as to the relative advantages and disadvantages of electric driving. I herewith submit the joint conclusions of a number of conferences on the subject with Mr. C. R. Makepeace, whose conservatism is well known. These are not the hastily formed opinions of a single discussion but the results of observation and experience covering the installation of a number of plants of which C. R. Makepeace & Company have been the engineers and for which I have furnished the machinery and equipment.

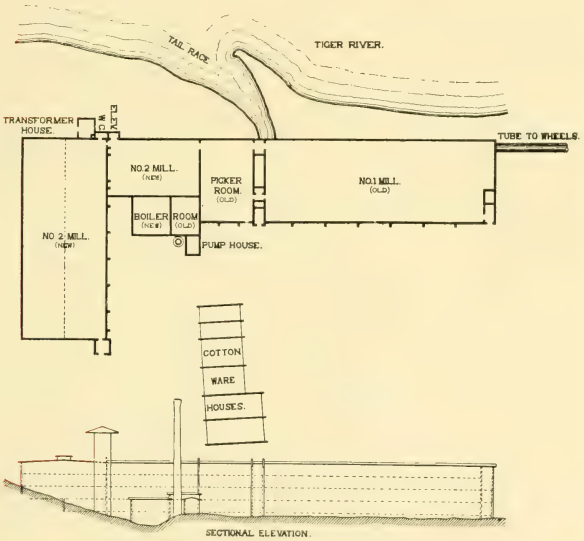
Electric Transmission for the Development and Utilization of Water Powers.

For great distances the generation and transmission of power by electricity is in a class by itself, and does not enter into a comparison of systems. Under this heading are included not only power companies generating and transmitting electric power for sale, and of necessity mill companies purchasing such power; but also mill companies developing and utilizing water powers for driving their own mills.

For some time the opinion of both engineers and mill men has gradually tended towards electric transmission as the only proper solution in the case of almost all mills driven by water power. Even the most successful water power mills mechanically driven are located under great disadvantages: not only are light and ventilation sacrificed, but the excavations and foundations have been heavy, and even then the machinery arrangement is not at all as satisfactorily disposed of as it could have been if the question of location could have been ignored. The water development itself is generally a compromise. On the other hand, with electric transmission, the mill buildings can be located on relatively high and level ground, thereby securing the very best possible arrangement from both an engineering and manufacturing standpoint. In the development of the water power a considerable economy can be effected, and often a gain in efficiency secured, by not having to consider and provide for a suitable location for the mill buildings. The dam can be built at the most suitable point, and generally without the same relative expense for head and tail races. Incidentally, so far as the generators are concerned, the electrical apparatus itself for water power development is comparatively inexpensive, because they are generally direct coupled to water wheels, which can be so proportioned as to permit the use of fairly high speeds.

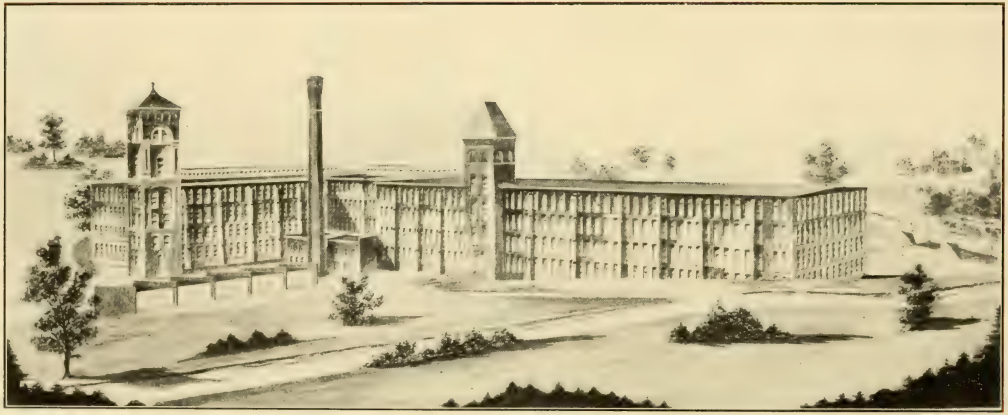
And just here attention may be called to the extraordinary

adaptability of electric transmission to subsequent developments of a water power above or below the original installation. The No. 2 Mill can be built adjacent to or even as an extension to the No. 1 Mill, instead of being separated from it by a distance of several miles,—with all the advantages to be gained by the concentration of the buildings from a manufacturing standpoint, not to mention avoiding the additional fixed charges that would have been rendered necessary in the way of providing additional railroad facilities and a new mill village with its attendant stores, schools, churches, etc.



The recent addition of a 35,000 spindle equipment to the **Tucapau Mills** affords an excellent illustration of this class. A new shoals was developed, and the power was transmitted back to the No. 1 Mill, where the addition took the shape simply of an extension to the existing mill.

The sketch plan above shows both the old mill and the new extension. The tube entering the main mill to the right brings water to the wheels from the dam a few hundred feet above the mill ; the location of the wheel-house is indicated by the position of the tail-race. The old mill was driven mechanically by ropes from the water wheels ; the power was found inadequate, and a cross compound condensing engine was installed to supplement the power.



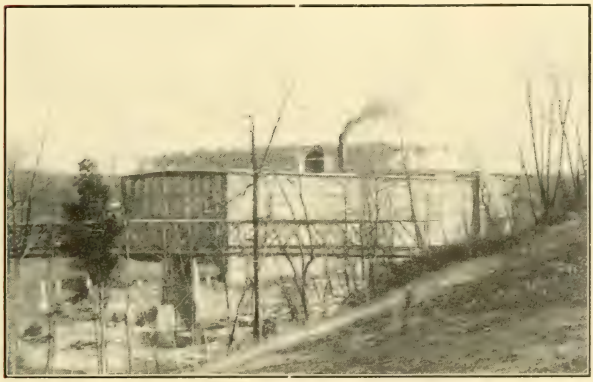
Tucapau Mills, Tucapau, S. C.
(Equipped by Stuart W. Cramer.)

C. R. Makepeace & Co., Engineers.

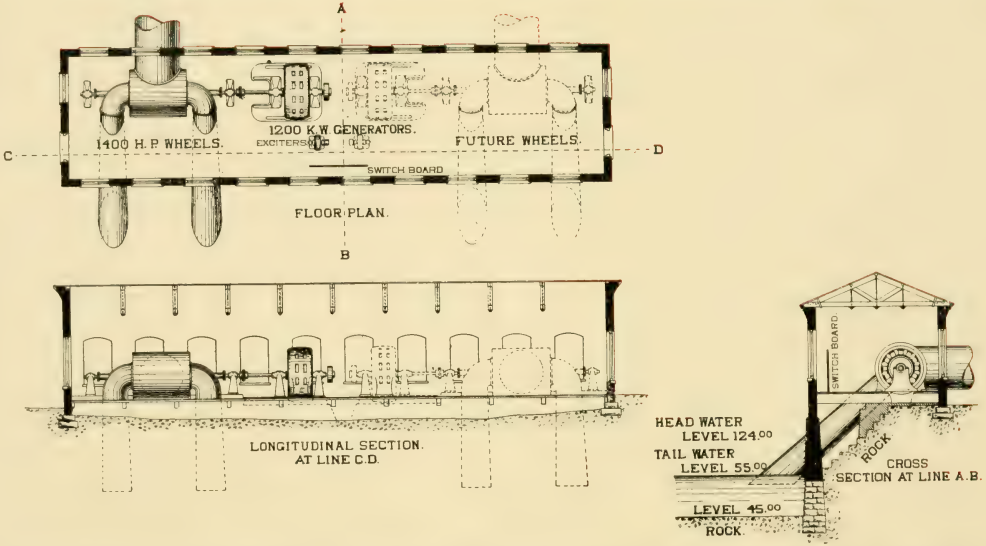
(The addition comprises all to the left of the stack.)

Electric Power Transmission, Continued.

View of Tucapau Mills from angle, behind the old mill; the new mill to the right extending forward.



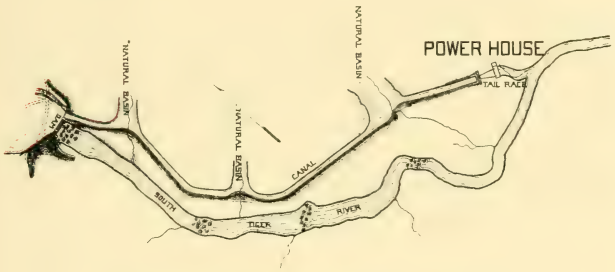
Another view of the completed mills from behind and above the old mill.



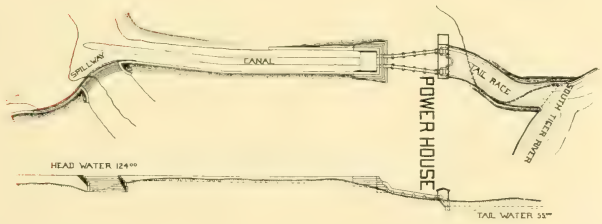
The above diagram of the **Tucapau Mills** new power house shows the installation of one unit, and provision made for the installation of another one of like size at some future date.

Electric Power Transmission, Continued.

The first installation for the new Tucapau Mill consists of a pair of 27 inch McCormick turbines, under a working head of 70 feet, developing 1400 horse power, at 400 revolutions per minute. It is direct connected to a 1200 K. W. General Electric 10,000 volt, three phase, 40 cycle, Generator. The power is transmitted three miles.



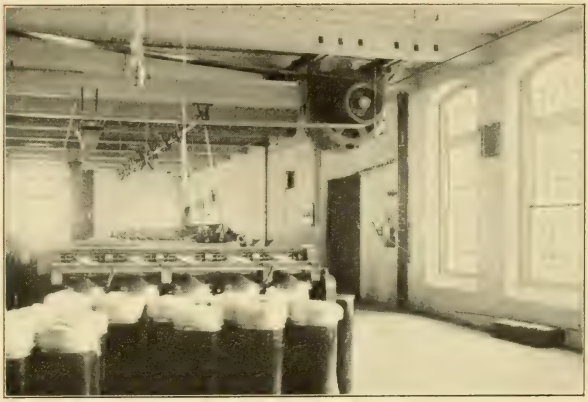
Topographical Sketch of the general development.



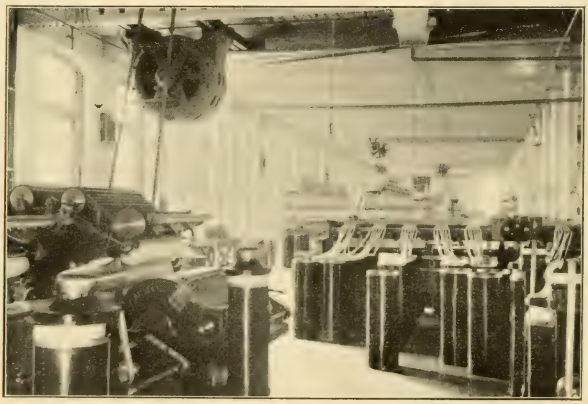
Enlarged Sketch (in both plan and section) of the Canal as it approaches the power house.

The water development in this case is a particularly attractive piece of work from an engineering standpoint, and I take pleasure in showing the general details of it in the above sketches, which explain themselves.

The two following cuts illustrate a motor installation at the **Tucapau Mills**:



The cut above shows the pulley side of a motor, and the belt driving countershafting; the wiring mains are also shown up in the corner on the right hand side, including the starting switch and connections down on the side wall. This picture is taken looking toward one corner of the card room.



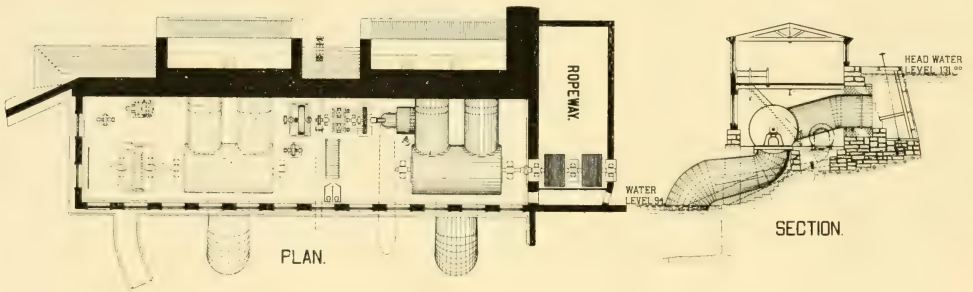
The above cut is taken from a photograph of the same motor taken from the opposite side—over in the corner of the room.

These motors are of the General Electric Form L type; near the bottom of the motor shown above will be noted the switch lever operating the starting resistance. (See also pages 784, 788, and 790.)

Electric Power Transmission, Continued.

The Washington Mills, at Fries, Va., illustrates another case where in the original water development provision is made for electrically driving future extensions.

The first installation consists of a pair of McCormick 54 inch turbines, with two sheaves for rope driving. They operate under a head of 37 feet, and at 160 revolutions develop 2600 horse power.



The dotted lines to the left show the second installation, which will consist of another pair of wheels direct connected to a polyphase generator for driving electrically the extension that is planned to be made in the near future.

Incidentally, it will be noticed, as shown above in solid lines, to the left of the original installation a comparatively small third turbine was installed for driving the fire pumps (by frictions), and a 250 K. W. Westinghouse three-phase A. C. Generator, which furnishes not only current for lighting but also power for pumping, elevators, and for a number of other minor purposes.

Electric Power Transmission, Continued.

Washington Mills, Fries, Va.
(Equipped by Stuart W. Cramer.)

C. R. Makepeace & Co., Engineers.

The above cut shows the Washington Mills as they will appear when completed; the full outfit of machinery will then consist of 105,000 spindles and approximately 4,000 looms.

For the present the carding and spinning are on the third and fourth floors and the looms are on the first and second floors of the four-story building,—the whole outfit being mechanically driven by ropes direct from the water wheels; but when the new weave shed is built the looms will be moved into it from the main mill, and the space they formerly occupied will be filled up with the additional carding and spinning.

Electric Power Transmission, Continued.

The above diagram shows the extent of the enterprise when completed. The entire water development has already been made, and the solid lines above show the present mill, which contains approximately 50,000 spindles and 2,000 looms. The dotted lines show the weave shed that is to be added later.

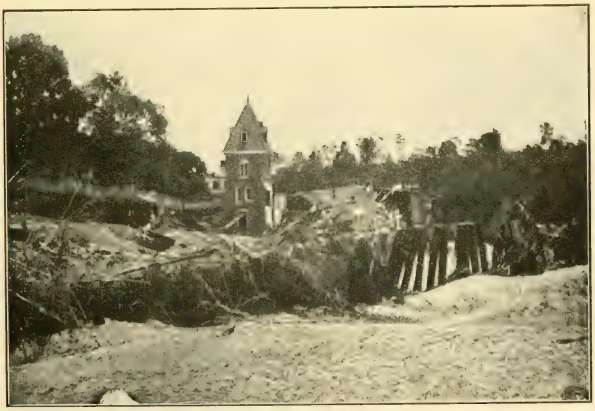
Electric Power Transmission, Continued.

The recent disasters at the Clifton and Pacolet Mills in South Carolina, in which not only whole mills disappeared and others were badly wrecked, but portions of the villages themselves were washed away with attendant loss of life, have called attention to the element of danger which has not heretofore been considered in the question of location. Even though such catastrophes are not expected to be repeated, still in the future consideration must be given to the fact that they have happened and must be guarded against not only there, but elsewhere. The directors of the Clifton Company, therefore, have wisely decided that while they will restore their mills which were only partially wrecked, their No. 3 Mill which was totally washed away will be erected upon high ground at a safe distance, and electrically driven from the old power house that will be rebuilt.

The following pictures illustrate the necessity for giving this new feature in the element of location its proper weight:

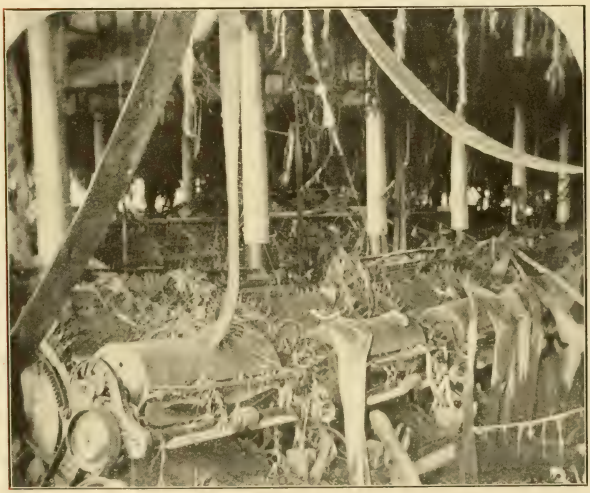
The above cut shows the **No. 3 Clifton Mill as it originally existed mechanically driven.**

View taken of the ruins after the washing away of the Clifton No. 3 Mill shown on the preceding page.



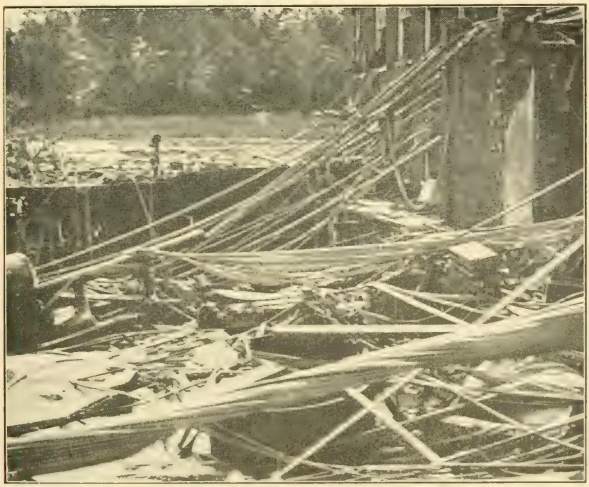
The above shows the partially wrecked Clifton No. 1 Mill in the background, with the upturned electric car line partially covered with debris in the foreground.

A closer view of the damaged end of Clifton No. 1.



The card room on the second floor of this same Clifton No. 1 Mill after the waters receded.

The weave room on the ground floor of the Clifton No. 1, showing mud and sand washed in.



Clifton No. 2 was also badly damaged.
Thousands of yards of cloth and warps were washed from the looms and left hanging through the windows.

Electric Power Transmission, Continued.

New No. 3 Mill of the Clifton Manufacturing Co. C. R. Makepeace & Co., Engineers.
(Equipped by Stuart W. Cramer.)

The Company contemplate operating at some future time 80000 spindles at this point although they are intending to start with 36000 spindles at present.

The No. 3 Mill will be electrically driven, the power plant being located on the site of the old power plant which mechanically drove the old mill that was destroyed during the freshet of 1903. This new installation will consist of two pairs of McCormick horizontal 42-inch turbines, supplemented by a 750 H. P. tandem compound condensing Corliss engine.

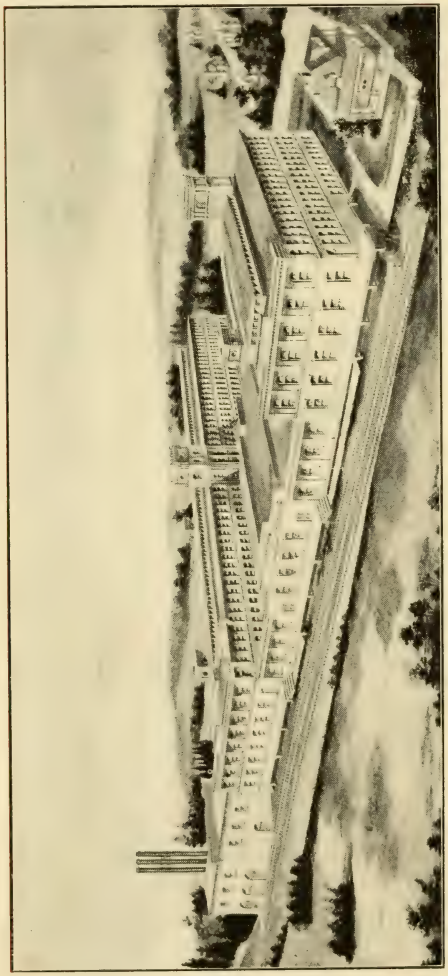
Power for the future addition will be generated either by a direct connected Corliss engine, or a steam turbine as seems most advisable at that time.

Electric Power Transmission, Continued.

Diagram Showing the Relative Positions of the New and the Old No. 3 Clifton Mills.

Both the engine and the water wheels to be used in this first installation were a part of the power plant of the old No. 3 Mill; while the mill was completely destroyed, the power plant was but slightly damaged. There will be coupled direct to the water wheel shaft a General Electric 1500 K. W. three-phase 60-cycle alternator, running at 150 revolutions per minute, and furnishing current for both driving and lighting the new mill.

Electric Power Transmission, Continued.



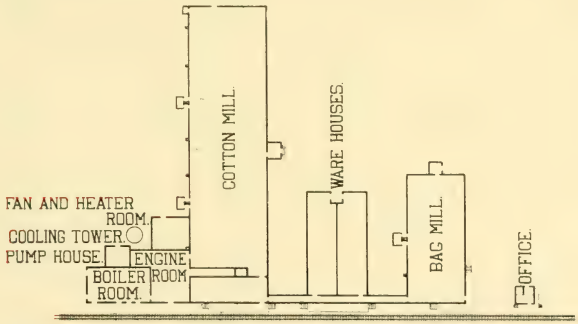
Golden Belt Manufacturing Co., Durham, N. C.
(Equipped by Stuart W. Cramer.)

C. R. Makepeace & Co., Engineers.

Electric Power Transmission, Continued.

As for a typical installation of the use of electric transmission of power generated by steam, the case of the **Highland Park Manufacturing Company**, of Charlotte, N. C., is a brilliant example. A full and complete description of it appears in Section IV., under the head of "**Mill Engineering.**"

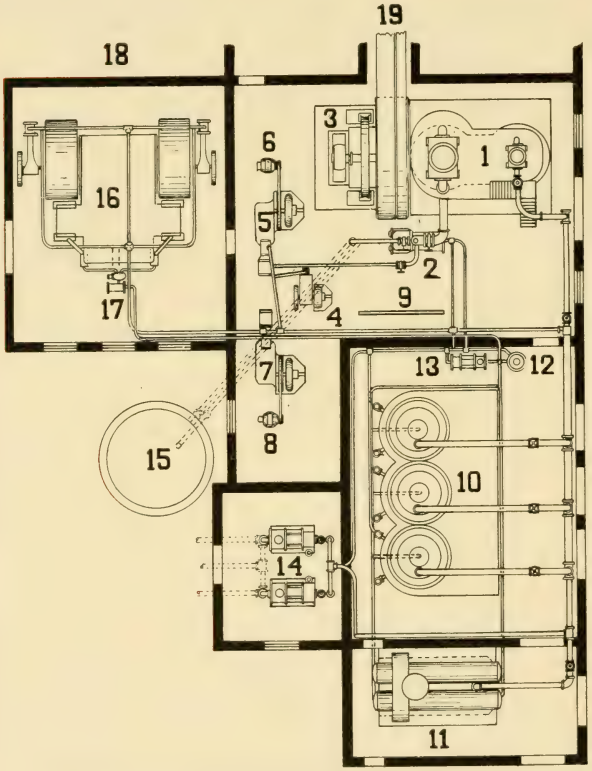
Another very interesting installation of this kind is that of the **Golden Belt Manufacturing Company**, of Durham, N. C. It shows not only the adaptability of electricity for driving the machinery in buildings not immediately adjacent to the power house, but also a unique combination of both a mechanical and an electric drive.



The cut on the opposite page and the diagram shown above give the relative locations of the buildings comprising this plant: all of which are connected across the front by a covered passage way, under which is the wiring tunnel.

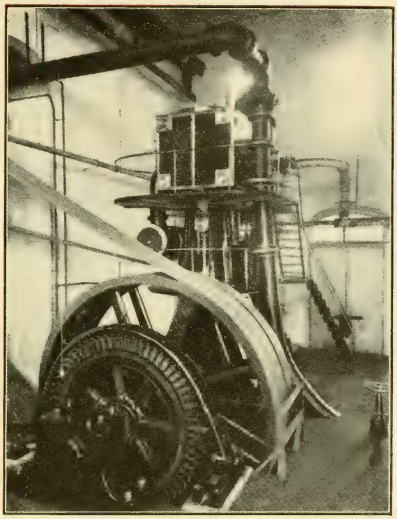
The original installation consisted of 15,000 spindles and about 500 looms, all placed on the first and second floors of the cotton mill building, driven directly by belts from a wheel on the main engine: the machinery in the bag mill being driven by electricity from a generator also mounted directly on the engine shaft next to the belt wheel.

Electric Power Transmission, Continued.



Enlarged View of Buildings Containing the Power Plant, Golden Belt Manufacturing Company, Durham, N. C.

The numbers on the above diagram refer to the equipment as follows : (1) Vertical Engine first installed. (2) Condenser. (3) First Generator installed. (4) First Exciter. (5) Second Engine and Generator installed. (6) Exciter for same. (7) Third Engine and Generator installed. (8) Exciter for same. (9) Switchboard. (10) Vertical Boilers first installed. (11) Horizontal Boilers last installed. (12) Feed Water Heater. (13) Feed Pump. (14) Underwriter Fire Pumps. (15) Cooling Tower. (16) Fan and Heater Apparatus. (17) Automatic Pump and Receiver. (18) Heating Tunnel. (19) Beltway.



The above cut illustrates the original power unit installed for this work. It consists of a Reynolds Vertical Cross Compound Condensing Corliss Engine, built by the Allis-Chalmers Company, with 22″ and 44″ cylinders by 42″ stroke, running at 110 revolutions per minute. The belt wheel is 18 feet in diameter, 54 inch face, crowned for two belts 36 and 17 inches respectively; the generator is a Westinghouse two-phase, 440 volt machine, of 150 K. W. capacity, furnishing current to the motors in the bag mill and for the lighting of the whole plant.

By referring to the diagram of the power plant on the opposite page, it will be seen that the original steam generating plant consisted of three vertical Cahall boilers of 250 H. P. each, with individual stacks. When the two other engines were added with their direct connected generators, another boiler was installed,—a horizontal Babcock & Wilcox 235 H. P. water tube boiler, also with its individual stack; this boiler is arranged to be one of a battery of two at some future date.

The condenser is of the Worthington horizontal jet type, with cooling tower. The condenser proper is a 12″x15″x15″ independent jet condenser.

The exciter is a 10 K. W., 125 volt, compound wound,

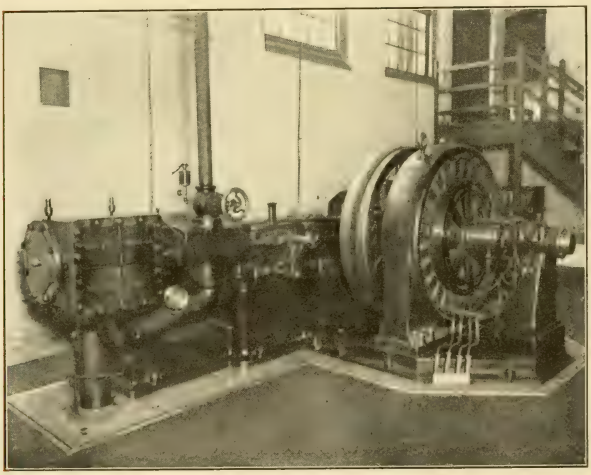
Electric Power Transmission, Continued.

six pole, direct connected to a Buffalo 6″ x 8″ horizontal center crank automatic engine.

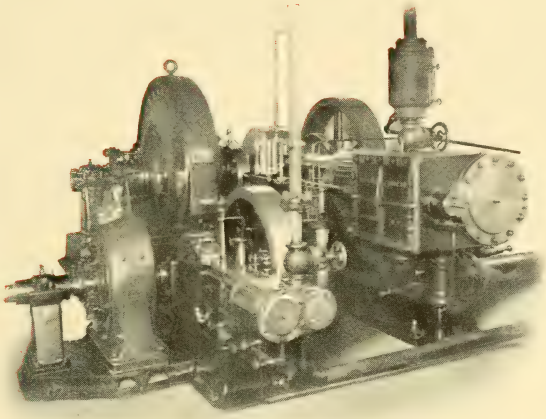
On the diagram are also shown the Buffalo heating and ventilating apparatus, consisting of two three-quarter housing steel plate fans having blast wheels 106″ x 53½″, direct connected to two 8″ x 10″ center crank engines.

Also two Worthington 750 gallon Underwriter fire pumps, 16″ x 9″ x 12″, one with automatic attachment, are shown cross connected for fire purposes.

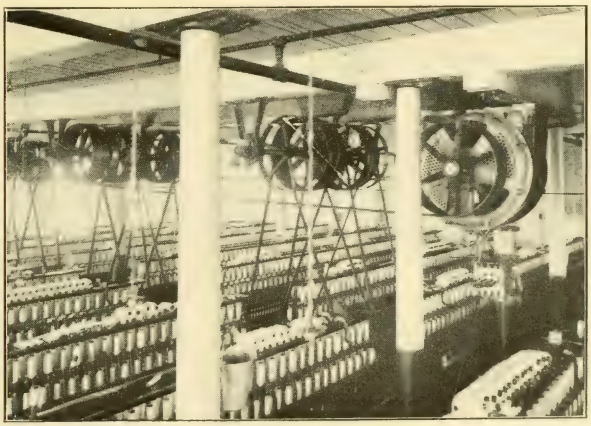
The boiler feed pump is also a Worthington 7½″ x 4½″ x 10″.



In the original plans an unfinished basement, which was practically a complete story, had been left for whatever use the future requirements of the plant might dictate. It very soon transpired that additional textile machinery would be needed to furnish cloth to meet the increased demand of the bag mill, and so approximately 5,000 spindles and looms to suit were added. The power for this work was easily taken care of by installing another small unit, consisting of a Buffalo Tandem Compound Engine, with 10 and 16 inch cylinders by 12 inch stroke, 300 revolutions per minute; with a Westinghouse two-phase 440 volt generator, 75 K. W. capacity, direct connected to it,—all connected on the switchboard interchangeably with the unit first installed. The above cut shows this installation.



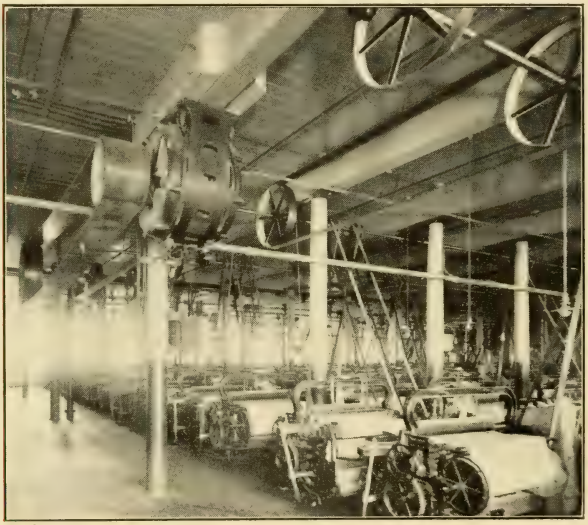
Later it was found that the bag mill still required the installation of more producing machinery in the cotton mill, and so another 5,000 spindle outfit was put in, and a third power unit added to take care of it. The above cut shows this third unit, with the small direct connected exciter set in the foreground on the left.



Westinghouse Inverted Motor Driving Spinning.

Electric Power Transmission, Continued.

It consisted of a Buffalo Tandem Compound Engine, with 11″ and 18″ cylinders by 14″ stroke, 250 revolutions per minute, with a Westinghouse two-phase, 440 volt, generator, 100 K. W. capacity, direct connected to it.



Westinghouse Inverted Motor Driving Looms.

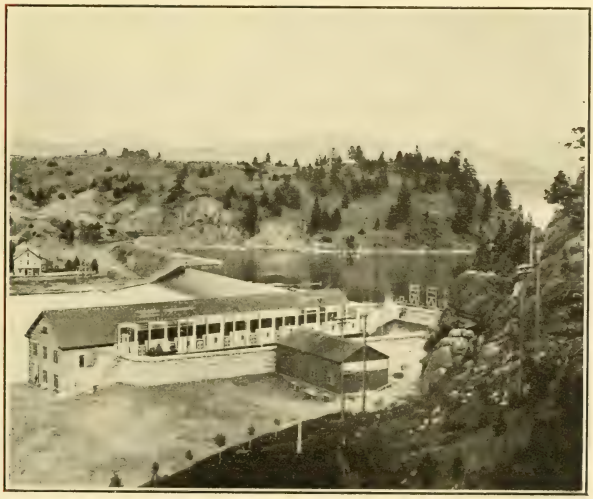
It will thus be seen that this job is not only unique in combining both the mechanical and the electric drives, but also that it furnishes an unusually good illustration of the ease and facility with which the necessary power may be provided to drive different additions to the original plant. It is often impossible to predetermine the character and extent of such additions so that it is practically out of the question to provide for them in a mechanical drive without wasteful, extravagant, and even possibly useless expense therefor.

Mr. T. B. Fuller, President of the Golden Belt Manufacturing Company was quick to see that the electric drive possessed special advantages in his case and adopted it, though at that time there were only three or four electrically driven mills in the country. Subsequent events, however, have abundantly proved the soundness of his conclusions.

Electric Power Transmission, Continued.

I have selected the Missouri River Power Company's plant as a type of a company generating and transmitting power for general industrial purposes. This case is of particular interest to Southern manufacturers, because the conditions are not greatly different from those that exist at a number of Southern points. Similar installations are now being made or are in use at the Narrows of the Yadkin in North Carolina: at the Catawba Power Company's plant near Rock Hill, S. C.: at Anderson, S. C.; etc.

The generating plant is located at the mouth of the Black Rock Canon of the Missouri River, seventeen miles from Helena, and sixty-five miles from Butte. The total length of the dam from bank to bank is approximately 900 feet. The foundations of the power house, canal walls and abutments are on granite bed rock, but that part of the dam in the middle of the stream between abutments is a timber crib rock filled. The dam forms a lake or reservoir seven miles long and more than six square miles in area.

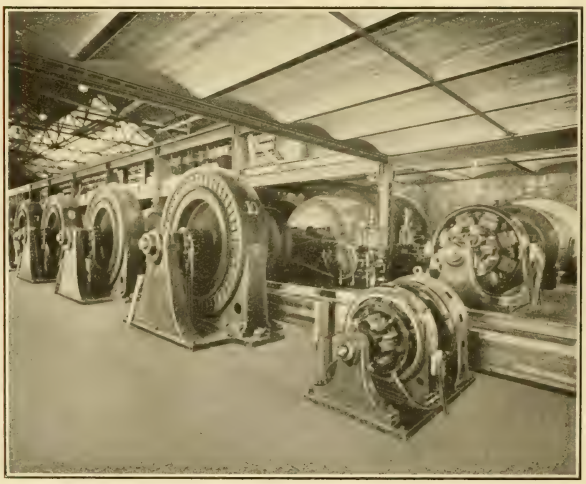


The above cut shows a general view of the dam, power house, and canal, including racks and gates. The canal is

Electric Power Transmission, Continued.

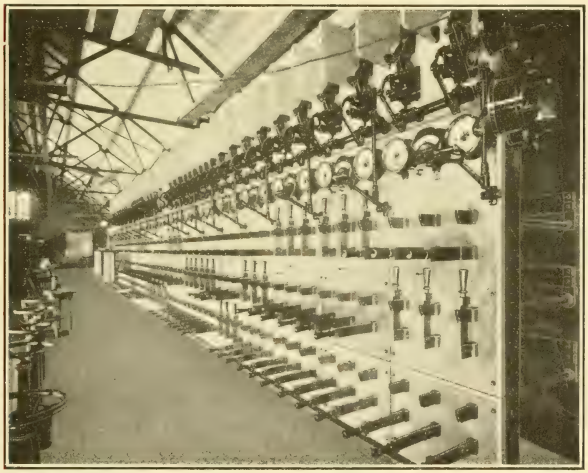
lined throughout, including the bottom, with Portland cement concrete. There are ten main gates, each 10 feet 4 inches by 17 feet 10 inches high, 16 inches thick in the center, made of Oregon fir. The gates slide in structural steel guides built in the masonry. The device for lifting the gates is unique, consisting of a car with the necessary mechanism, traveling on rails in front of the gates parallel to the east wall of the canal. The car receives its power from a 10 H. P. direct current motor supplied with current from a trolley.

The power house is 228 feet long by 50 feet wide, with a gallery 18 feet in width extending the entire length of the building on the west side. Adjoining the main power house on the east wall of the canal is a transformer room 150 feet long. The building is entirely of masonry and steel, with the exception of the roof and the main floor. The roof trusses are of steel, and the roof is covered on the outside with corrugated iron ; the floors are of steel and concrete construction.



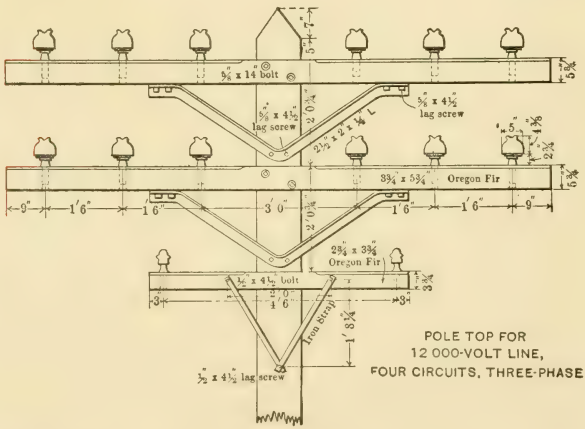
The above cut shows the general arrangement of the water wheels direct coupled to the generators, with the exciters in the foreground. There are ten pairs of water wheels driving the main generators, of the McCormick type, built by the S. Morgan Smith Company. There are two bearings on each shaft.

shaft, one on the outside of the wheel nearest the canal and the other nearest the draft chest. A third bearing is located entirely outside the wheel case next to the generator coupling. This bearing is also designed to take thrust in a direction parallel to the shaft. Two single wheels and one pair of smaller wheels drive the exciters. There are ten 60-cycle direct coupled generators, one to each pair of water wheels, each designed to deliver three-phase A. C. current, at 550 volts, running at 157 revolutions per minute. Each machine has a rated capacity of 750 K. W. at 80 per cent. power factor. All the electrical machinery and apparatus was furnished by the Westinghouse Electric & Mfg. Co.



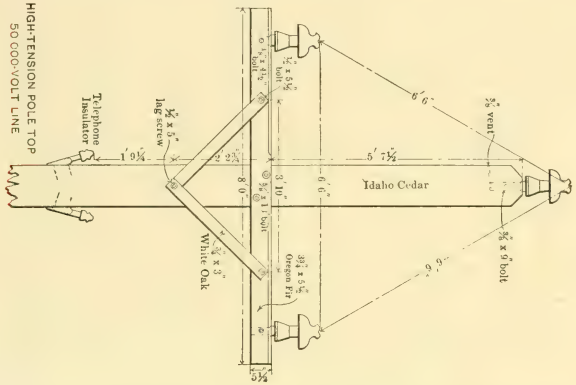
The switchboard is of blue Vermont marble, located on the gallery floor in the center of the station. The transformers are immediately in rear of and below the switchboard. There are twelve of 330 K. W. each for the 12,000 volt transmission circuits to Helena, seventeen miles away, and there are six of 950 K. W. each for the 50,000 volt transmission circuits to Butte, sixty-five miles away. The 12,000 volt transformers are oil insulated and air cooled, arranged in four groups for three phase Delta connection. The 50,000 volt transformers are oil insulated, water-cooled, arranged in two groups for Delta connection. The lightning protection for the 12,000 volt lines is of the Standard Works Type "R", consisting of choke coils and gaps. For the 50,000 volt lines a new and special apparatus has been designed, consisting essentially of two parts,—static interrupters and lightning arresters proper.

There are three main pole lines from the generator station: One carrying four power circuits each consisting of three No. 4 solid copper wires, and a telephone circuit of two No. 10 copper wires; this line extends to the East Helena sub-station.


5/8" x 14" bolt
5/8" x 4 1/2" lag screw
5/8" x 4 1/2" lag screw
2 1/2" x 2" x 1/4" L
3 3/4" x 5 3/4" Oregon Fir
2 3/4" x 3 3/4" Oregon Fir
1/2" x 4 1/2" bolt
Iron Strap
1/2" x 4 1/2" lag screw
POLE TOP FOR
12 000-VOLT LINE,
FOUR CIRCUITS, THREE-PHASE

The above cut shows the general design of the pole tops for these four 12,000 volt three-wire circuits. The main

wires are not transposed, but the telephone wires are reversed in position at every third pole; the poles are spaced an average distance of 110 feet apart.



The above cut shows one of the pole tops for the 50,000 volt transmission lines. There are two separate pole lines for these high tension currents carrying three pure copper cables, each 78 inches apart and of 106,000 circular mils in area. The insulators and sleeves are of glass; the pins are also insulated by being first dried and then boiled in paraffine. The insulation of the circuits depends upon the insulator pins and sleeves combined. The glass sleeves are not connected in any way with the insulators, but merely rest on shoulders of the pins. The object of the sleeves is to prevent the surface of the pins from becoming wet in a driving rain, thus permitting leakage; this function they would not be able to perform were not the pins specially treated, as above described. Each of the main circuits is transposed five times, making two complete turns between the power house and the Butte sub-station. The telephone circuit, as shown in the cut, is on one pole line only, and is composed of two No. 10 copper wires on double petticoat pony insulators; this circuit is transposed every fifteen poles. The two high tension pole lines are parallel and 50 feet apart where the nature of the ground will permit, the standard spacing between poles being 110 feet, with a maximum of 150 feet when required by the nature of the ground. The angle turn on any one pole does not exceed 20 degrees.

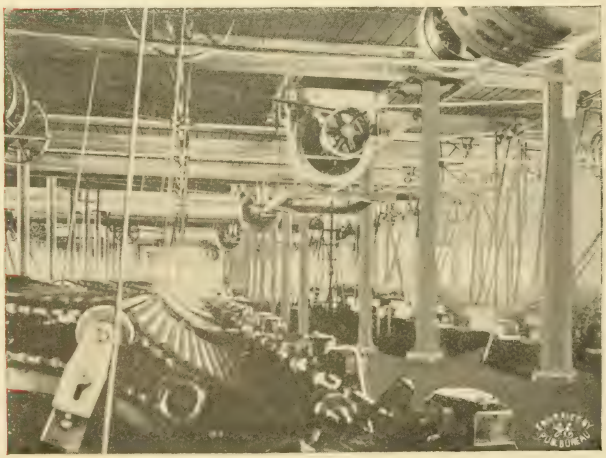
As for the details of the distribution at the sub-station, it is not a matter of particular interest in this article.

Electric Power Transmission, Continued.

TYPICAL MOTOR INSTALLATIONS.

The following cuts illustrate in general the method of installing induction motors in cotton mills.

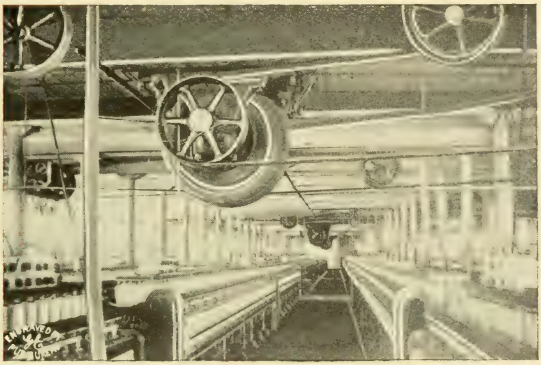
G. E. 75 H. P. Motor mounted on the wall in the card room.



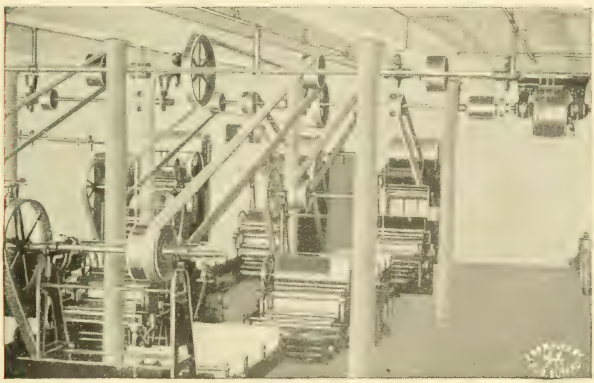
G. E. Inverted Motor in card room with two pulleys on each end of the motor shaft.

Electric Power Transmission, Continued.

Typical Motor Installations, Continued.



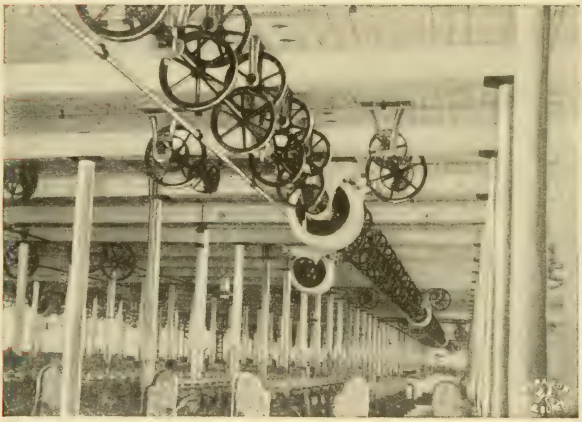
G. E. Inverted Motor in spinning room with two pulleys at each end of motor shaft.



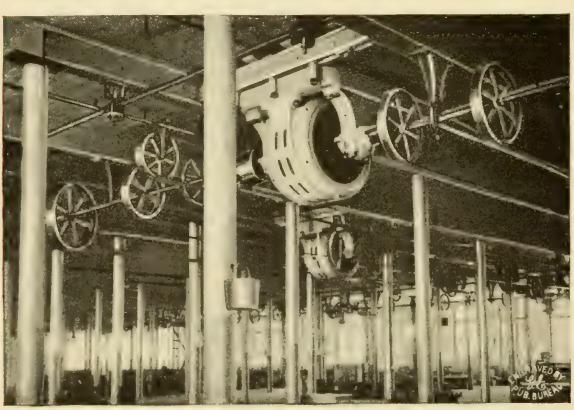
G. E. Inverted Motor in picker room coupled direct to shafting.

Electric Power Transmission, Continued.

Typical Motor Installations, Continued.

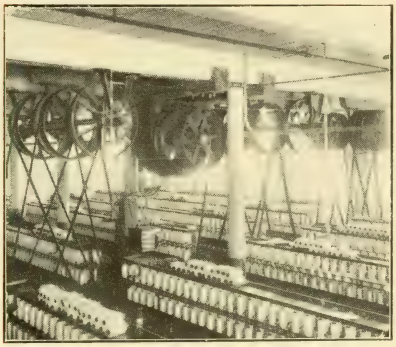


G. E. Inverted Motor direct-coupled to line shafting in card room, also driving spinning through the floor in the room above.

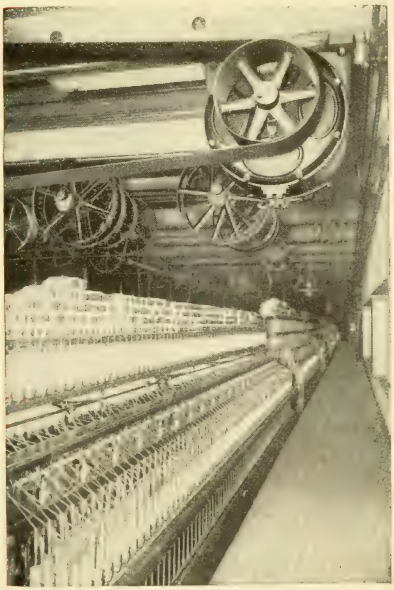


A closer view of same.

Typical Motor Installations, Continued.

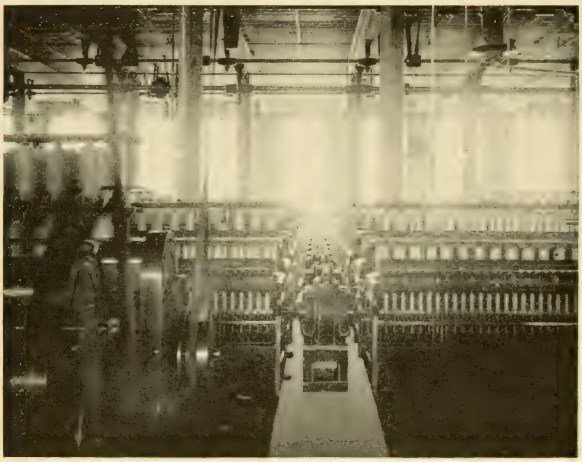


Westinghouse Inverted Motor driving spinning.



Westinghouse Inverted Motor in card room, with one pulley on each end of motor shaft, driving roving frames through countershafting.

Electric Power Transmission, Continued.



The above cut illustrates G. E. motors, each driving two spinning frames, placed directly between them and direct connected on either end to the spinning frame shaft through a friction clutch. The Anderson Cotton Mills, at Anderson, S. C., C. R. Makepeace & Co., Engineers, placed forty-six of these motors in their spinning room in the first instalment. When the mill was doubled up, they added forty-eight more. The old motors, as shown in the illustration, were placed on boxes between pairs of spinning frames. The new ones, however, were placed on structural iron supports bolted to the heads of each spinning frame. This arrangement dispenses entirely with the use of all belting in driving spinning. The current is furnished by the Anderson Electric Light & Power Company, whose plant is ten miles away; between the water wheel and the spinning frame there is therefore not a single belt or auxiliary shaft! Messrs. Brock and Ligon, of the Anderson Mill, report absolute uniformity of speed of the front roll, which is the determining factor in the production of a spinning frame The advantage of this is obvious, for variations of 5% and even 10% in the speed of the front rolls of different frames in the same mill are not uncommon. The objection to this method of driving is that only the constant speed motors are the ones that seem

Electric Power Transmission, Continued.

to be feasible for this work, which means that a mill so equipped can only spin a constant number of yarn. If this can be said definitely to be the future policy of the mill, such a drive can be recommended; such a prediction, however, will in most cases be hazardous.

The Performance and Behavior of Motors.

As stated elsewhere the running load is not the maximum load. For instance, the power has been known to vary as much as 15% in one day in the same mill. The maximum is always at the starting up in the morning when the machinery is cold. As things warm up and the oil thins out, the power drops to normal,—which requires anywhere from one-half an hour to two hours, according to local conditions.

It is not to be understood that this is peculiar to an electric drive, however, for it exists even to a greater extent in the case of a mechanical drive.

I am indebted to Capt. Ellison A. Smyth for a condensed summary of tests of their motors made a couple of years ago. The results are particularly valuable, because they represent an installation of comparatively long standing, the Pelzer having been the second or third mill in the country to adopt the electric drive.

THE PELZER MANUFACTURING CO.

PELZER, SOUTH CAROLINA, Nov. 18, 1902.

MR. STUART W. CRAMER,
Charlotte, N. C.

DEAR SIR:—

In compliance with your request of recent date, I am sending you a condensed summary of some tests of our electrical machinery, made last February, by our engineer, Mr. W. H. Trammell, who was formerly with the testing department of the General Electric Co.

The motors, with their machinery, will be taken up separately, in numerical order.

There are two forms of Motors, the Form A, which was the original type installed, and which had very large air-gaps, and the newer Motors, which are known as Type B, and are of the new Form K type, manufactured by the General Electric Co., and in which the air-gap is much smaller than the older type.

Motor No 1. Drives two moistening pumps and one heating and ventilating fan, E. H. P. without fan 17.4; Amp. 62; Volts 236; P. F. 51.5%. With the fan, E. H. P. 63.8; Amp. 132; Volts 228; P. F. 89%.

Motor No 2. Drives the usual cloth room machinery, consisting of two baling presses, two stitchers, three brushers, and four folders, one freight elevator and one conveying belt for cloth from stamper to presses. This motor is rated 50 H. P., test giving 25½ E. H. P.; Amp. 62; Volts 238; P. F. 74.6%.

Motor No. 4. Rated 130 H. P., Form A. Drives 400 Northrop

Electric Power Transmission, Continued.

Looms, E. H. P. 129; Amp. 275; Volts 227; P. F. 87%; Friction of Motor and Shafting 24.7 H. P.

Motor No. 5 Rated 130 H. P., Form A. Drives 390 Northrop Looms, 1 freight elevator; E. H. P. 127; Amp. 260; Volts 228; Friction of Motor and Shafting 25.5 H. P.

Motor No. 7. Rated 75 H. P., Form A. Drives 11 Finishers and 24" Cotton Fan in Picker room; E. H. P. 56.5; Amp. 128; Volts 231½; Friction of Motor and Shafting 9.15 H. P.; P. F. 81%.

Motor No. 8. Same as above. Drives 11 Intermediate Pickers; E. H. P. 51; Amp. 120; Volts 233; P. F. 78.6%; Friction of Motor and Shafting 7¼ H. P.

Motor No. 9. Same as above. Drives 11 Pickers; E. H. P. 78½; Amp. 166; Volts 233½; P. F. 87.5%; Friction of Motor and Shafting 8.6 H. P.

Motor No. 10. Same as above. Drives 11 Breakers, 1 Exhaust Fan for Condensers; E. H. P. 39; Amp. 100; Volts 232½; P. F. 72%.

The four Motors as given above are directly connected to line shafting running 600 revolutions per minute, from which the belts drive directly to the picker machinery.

Motor No. 11. Rated 130 H. P., Form B. Drives 49 Fly Frames, and 6 Intermediates; E. H. P. 114; Amp. 243; Volts 229; P. F. 88.2%; Friction of Motor and Shafting 25.2 H. P.

Motor No. 12. Rated same as above. Drives 60 Cards, 36 Draw Frames and 10 Slubbers; E. H. P. 122; Amp. 246; Volts 231; P. F. 91%; Friction of Motor and Shafting 11.3 H. P.

Motor No. 13. Same rating and load as No. 12; E. H. P. 118; Amp. 245; Volts 233; Friction of Motor and Shafting 22.2 H. P.; P. F. 89.2%.

Motor No. 13½. Rated 30 H. P., Form A. Drives 20 Cards; E. H. P. 23 9; Amp. 55; Volts 231; P. F. 81%; Friction of Motor and Shafting 4 3 H. P.

Motor No. 14. Rated 130 H. P., Form B. Drives 36 Filling Spinning Frames, and 1 Exhaust Fan 24"; E. H. P. 112½; Amp. 242; Volts 230; P. F. 86%; Friction of Motor and Shafting 24.7 H. P.

Motor No. 15. Drives 14 Frames on No. 40 Filling, 8 Frames on No. 13, and 10 Frames on No. 20 yarn; E. H. P. 96; Amp. 217; Volts 232; P. F. 87%; Friction of Motor and Shafting 19 8 H. P.

Motor No. 16. Rated same as above. Drives 32 Filling Frames on No. 40 Yarn; E. H. P. 84½; Amp. 205; Volts 233; P. F. 82%; Friction of Motor and Shafting 22.8 H. P.

Motor No. 18 Rated same as above. Drives 14 Warp Frames on No. 28 Yarn; 6 on No. 13, and 4 on No. 17. E. H. P. 104½; Amp. 225; Volts 236; P. F. 85%; Friction of Motor and Shafting 22.5 H. P.

Motor No. 19. Rated same as above. Drives 12 Frames on No. 17 warp, and 12 on No. 20. E. H. P. 111; Amp. 237.5; Volts 232; P. F. 86.7%; Friction of Motor and Shafting 22.8 H. P.

Motor No. 21. Rated same as above. Drives 22 Frames on No. 13 Warp. E. H. P. 116.5; Amp. 245; Volts 232; P. F. 84 7; Friction of Motor and Shafting 22 H. P.

You will note that the power factors as given above are somewhat higher than would be expected from so large an induction motor load, but this is due to the fact that on the system there is a 400 K. W. rotary condenser and a 400 H. P. over excited synchronous motor, both of which tend to counteract the wattless currents.

Hoping that you will be able to select from these notes such information as you first asked us for, I am,

Yours truly,

ELLISON A. SMYTH,
President.

Dict. W. H. T.—mfg.

NOTES AND DEDUCTIONS.

In General.—Transmission by electricity is comparable to transmission by shafting, pulleys and belts or ropes, compressed air, or gearing; for, the problem in each case is but one of conveying power from one point to another,—generally from one shaft to another.

The efficiency, first cost, depreciation, repairs, etc., must be in each case given the same consideration. The question of adaptability and special advantages preponderates in favor of electricity.

Efficiency.—Modern polyphase generators and motors are of high efficiency,—the efficiency of each being in large units as high as 96 per cent. This characteristic of high efficiency for large units, however, is not materially different from that of other types of transmission, but what is of more importance is the fact that the efficiency practically remains the same throughout the life of the apparatus, there being no impairment of it due to wear and tear. Whereas, the efficiency of transmission by shafting and belts or ropes generally falls off, due to wear and tear, to unequal settling of points of support causing changes in alignment, and to other unusual or accidental conditions. It is true that careful attention will reduce this impairment in efficiency to a great extent; but even if care and attention could absolutely eliminate this lessening of efficiency, it would be unlikely to do so in actual practice, because of the difficulty of determining to what extent the impairment is taking place,—in other words, there is no convenient way of keeping a record of the performances, and so it is not uncommon to find losses of 25 per cent. to even 40 per cent. due to neglect, in systems of mechanical transmission. Of course, in the case of electric transmission, the recorded readings of the wattmeters show the condition of affairs all the time.

As a matter of fact, there is very little difference between the efficiencies of newly installed and properly designed drives, whether mechanical or electrical.

But just here it is well to make a distinction in the use of the term efficiency; efficiency under test conditions is one thing, but the "all day efficiency" or the "average for the year efficiency" is quite another thing. The load conditions affect efficiency very greatly. Take, for instance, the case of a mill that runs a part of its plant at night; an electric drive will show a very much greater efficiency than a mechanical drive. Or, if a mill puts in a mechanical drive arranged to double up at some future date, so that perhaps for a number of years the drive will be one of half load, the advantage in favor of electricity is even greater. In a mechanical drive, for instance, of 80 per cent. efficiency at full load, the half

Electric Power Transmission, Continued.

Notes and Deductions, Continued.

load efficiency is very likely to fall off to 60 or 65 per cent. Whereas, an electric drive under the same conditions would show an efficiency of at least 15 per cent. better.

Another phase of the question of relative efficiency is the extent to which the power is subdivided. The average electric drive really combines both mechanical and electric transmission, the character of the installation being determined by other questions as well as that of efficiency pure and simple. Of course, from an electrical standpoint, the ideal installation is the driving of each machine by a separate motor, thereby securing the maximum efficiency of electric transmission as well as entirely doing away with shafting, pulleys and belts. On the other hand, other considerations occasionally dictate the selection of an outfit that goes to the opposite extreme, viz., the installation of one or two large motors with practically the same arrangement of shafting, pulleys, belting, etc., that would be required if the main drive were direct from the engine or water wheels by belts or ropes. Generally, however, all the conditions involved will favor a middle ground in this respect,—the standard practice of to-day tending toward the elimination of head shafting and long lines of transmission shafting by motors of moderate size suitably placed to drive through the medium of countershafting sections of machinery instead of individual machines: the combined efficiency in such cases being the product of both the electrical and mechanical parts of the transmission, the latter consisting of countershafting and belts between the motors and the different machines.

No hard and fast rules can be laid down that will determine this question of the distribution of power and the extent to which it can advantageously be subdivided: but the elements involved are simple and apparent enough in each case, and the problem is an engineering one that can be easily worked out.

First Cost.—A great deal has been said about the first cost of a mill with electric transmission as compared to other types. On the one extreme, it is claimed that the cost of an electrically driven mill is but little greater than the cost of one of similar size mechanically driven, owing to the saving in the beltway, in heavy head shafting, hangers, and pulleys, and transmission lines of shafting with attendant belts or ropes, as the case may be.

On the other hand, the savings enumerated above in first

Electric Power Transmission, Continued.

Notes and Deductions, Continued.

cost are occasionally underestimated, the difference in the cost of the two types of mills being greatly exaggerated; and the actual difference in the cost regarded as excessive.

Whereas, experience does not bear out either one of these claims. An electrically driven mill is considerably more expensive than a mechanically driven one. This difference depends entirely on the extent to which the power is subdivided, which in turn depends upon a number of other considerations. The actual difference can only be determined by having preliminary plans made of the mill best adapted to suit the conditions in hand showing what would actually be required in each case. As to whether this additional cost outweighs the advantages that electric driving possesses, is a matter for each customer to decide for himself.

Depreciation and Maintenance.—The additional investment in the electrical apparatus causes a corresponding additional amount to be charged off for depreciation; besides, the depreciation on electrical machinery is greater than the corresponding depreciation would be for the items entering into the first cost of a mechanical transmission, including beltway. This is a point that will no doubt be disputed, but will hold, nevertheless.

Chargeable under this same heading may be added taxes and insurance on the extra cost of the mill equipped for electric driving.

A saving in oils and renewal of belting and ropes can, however, be credited to the electric drive.

***Special Advantages in Favor of Electric Driving.**—The simple matter of relative costs, both of investment and of operation, are undoubtedly unfavorable to electric driving as compared to mechanical; the adoption or rejection of it then depends entirely upon a proper appreciation of the special advantages in favor of it:

(1). Concerning future additions to the plant, the extent of the additions and the character of the goods to be manufactured need not be considered until the time actually comes to increase the plant.

If any attempt is made at forecasting the future and provision for it made in the mechanically driven mill, the cost

*See "Development of the Electrical Drive," by Sidney B. Paine, of the General Electric Company. The phraseology of a number of these conclusions has been borrowed bodily from Mr. Paine's well-expressed ideas on this subject.

Electric Power Transmission, Continued.

Notes and Deductions, Continued.

of the engine and its foundations, the arrangement of the shafting, pulleys, and hangers, etc., will add considerable to the cost of the first installation,—not considering the fact that circumstances may cause a change of opinion and that it may be undesirable to make the additions along the lines originally contemplated. Whereas, with the electrically driven mill additional power units can be added and extensions made as often as it may appear desirable, and each time without any regard whatever to what shape the next extension or alteration will take.

This is even more conspicuously true in the case of mills where the motive power is water instead of steam.

(2). Concentration of manufacturing buildings. As the location of these buildings is determined without reference to the location of the power house, they may be placed together and so arranged as to facilitate manufacture and reduce the expense of supervision.

(3). Improved light and ventilation are obtained by removing the power house away from the mill and by omission of belt tower.

(4). The generating plant may be also subdivided into two or more units. This insures against a complete shut-down in case of accident and also permits economical operation under partial loads. This also allows one or more sections of the mill chosen at will to be operated from either generating unit. All other sections will remain idle. This is not possible with the mechanical system, even though the generating plant may be subdivided.

(5). It permits the operation of one or more sections over time without driving the shafting in other sections.

Of course, in a mechanically driven mill, provision for this is often made by the introduction of friction clutches. Still the advantage in this case is clearly with the electric drive.

(6). Power in any section may be easily augmented, or addition may be made to the mill without stopping the mill or interfering with the existing shafting. It not infrequently happens, especially in older mills, that it becomes necessary to replace the main engine. It is either worn out or machinery has been added to such an extent that it is overloaded. In mechanically driven mills it will in such cases be necessary to shut down the mill. This will result in the loss of profits and of fixed charges during the shut-down, and what is quite as important, the scattering of the employ-

Electric Power Transmission, Continued.

Notes and Deductions, Concluded.

ees. With the electric drive no stoppage would occur as long as the old engine could be operated. A new engine and generator would be installed at any convenient point, and either supplement the old engine or take its place entirely and also carry any additional work that may be desired.

(7). The power required to operate any section may be readily measured. This can be continuously indicated by instruments placed in the engine room. These indicators enable the engineer in charge to detect at a glance any unnecessary consumption of power due to poor alignment of shafting, improper oiling, etc. The actual power consumed by any machine can be measured at any time by separate portable instruments.

(8). Variations in speed in one section, due to slipping on such belting as is still retained, are not communicated to other sections.

(9). Steadiness and uniformity of speed. This is occasioned by omission of many belts, and results in greatly increased production, as shown above, and in less repairs on the machinery, especially on the looms.

(10). Uniformity in size of shafting. With a properly designed subdivision of the electric drive the diameter of the shafting is determined solely by the width of the bay. All pulleys and hangers are therefore of the same bore, except on those lengths of shafting which carry the receiving pulleys.

(11). There is less difficulty in keeping the relatively shorter lengths of shafting aligned.

(12). The doing away with a considerable amount of shafting, pulleys, hangers, and belting, which means better light, less dust, less oil and grease to drip or otherwise soil the product, and less personal danger to the operative.

In Conclusion.—There is no question but that in a comparatively short time the numerous water powers of the South will be developed and relatively cheap power offered in connecting links over large sections of country. Cotton mills installing their own generating plants, whether steam or water driven, should therefore bear in mind this fact, and install apparatus of standard frequency and type, that they may be in a position to interchange with power companies as exigencies may require.

(See pages 845-9.)

Electric Power Transmission, Continued.

Remarks on the Arrangement and Disposition of the Motors.

(At the risk of repetition, it seems advisable to emphasize a few of the points embraced under this heading.)

The extent to which it seems best to subdivide power by the use of motors in an electrically driven mill is one of the most puzzling problems the engineer has to deal with. It goes without saying that the ideal drive is like that of the spinning in the Anderson Cotton Mills, a direct connected motor to each machine or to each pair of machines. For many reasons, however, this is practically out of the question; and, motors then must drive shafting by which in turn groups of machines will be driven by belts, as usual.

The best practice in such a case would then undoubtedly be the direct coupling of line or countershafting to either one or both ends of the motor shaft, according to the length of the section to be driven. The objection that is at once apparent to this method of driving is the fact that motors in such cases will generally be expensive, owing to their relatively slow speeds; this has not been much of a factor in a number of forty cycle plants heretofore installed, but is becoming considerable of a question where the present tendency is toward sixty cycle apparatus. At the same time, it will be found not only advantageous but feasible to a greater or less extent in almost all mills electrically driven.

Motors are generally built with their shafts extended to receive a pulley on each end, and oftentimes to receive two pulleys on each end. The motor shaft then becomes practically a short line shaft, permitting the taking off of two to four belts in either one or opposite directions. This is particularly found convenient in driving spinning and roving frames; the motors can be so proportioned in size that they will drive a number of different countershafts, each in turn driving four frames.

Of course, the introduction of more belts means the possibilities of greater slip. The amount of slip varies from day to day and according to atmospheric conditions, and also from month to month according to the carefulness and closeness with which they are watched by overseers and superintendents. The amount of slip in a mechanically driven mill varies from 3% to 10%; and varies not only from time to time, but in different machines of the same class and on the same

Electric Power Transmission, Continued.

work. It is impracticable to increase the speed of the engine to take care of this slip, because some machines would then be over-speeded and others under-speeded; it is true the average would be right, and the production ought to be so were it not for the fact that the work would not run well. Now, with an electrically driven mill the amount of slip may be said to be reduced directly in proportion to the number of belts eliminated, and the production will be accordingly increased.

The problem of the extent to which the power is to be sub-divided, therefore, is one that will be a compromise both from the standpoint of the manufacturer and the engineer.

Elsewhere in this book will be published revised tables of the horse power required to drive cotton machinery. In the past this has not been a matter of any great consequence as long as information on the subject was fairly approximate. There had been definite enough information accumulated as to the amount of horse power per thousand spindles required on different classes of work; therefore it was no trick to select an engine of the proper size to drive a mill of a certain size. It might be said that the sizes of belts would have had to be accurately determined for the power actually required by each frame and each section; but as a matter of fact there was always figured enough margin to take care of reasonable variations from the calculated horse powers. With the advent of electricity for the transmission of power in cotton mills, however, and the sub-division of that power, the actual load that each motor would be called upon to drive has become a matter of the greatest importance. To get the best results both in efficiency and power factor from motors, they should be loaded about up to their rated full load capacity; the small diurnal variations due to atmospheric and other changes can be absorbed by them in the nature of an overload without serious objection or appreciable loss.

And finally, it is not out of place to mention that in order to get the full benefits from an electric drive, closer attention must be paid to details. There is no use in going to the expense of installing such a drive, with its possibilities of greater uniformity of speed and less slip, with consequently increased production; and then either wholly or partially

Electric Power Transmission, Continued.

nullify those advantages by
Inattention to the few remaining counter belts,
Careless spindle banding,
Allowing the machines to get sticky and gummy by their not being properly cleaned,
The use of inferior oil,
Machinery out of alignment—particularly long frames,
Etc., etc.

When motors are first installed the machinery should be carefully watched until everything is limbered up and running under normal conditions to the best possible advantage. And then by keeping a record of the readings of the wattmeters on the different feeder panels, any deviations from that standard will be readily detected. And then by checking up the performance of each motor in that circuit with the portable instruments that should be provided for that purpose, the one or ones requiring excessive power can be readily detected, and the trouble immediately localized so it can be readily found. The one great advantage of electric driving above all others is the ease and facility with which the performance of the machinery in a mill so driven can be kept up to the very highest possible standard. The daily record of the wattmeters will promptly call attention to any falling off from the standard, and then it is only a question of willingness and attention to duty upon the part of the overseers and the superintendent.

Not only the generators in the power house, but the motors throughout the mill, and the transformers, should be kept clean. This, with the exception of oiling at the proper intervals, is practically the only attention to motors required. Small air compressors mounted on trucks with direct connected motors are frequently employed for cleaning the armatures and other parts of the generators and motors by compressed air at about twenty pounds pressure. They are also convenient for cleaning the parts of transformers that can not be reached by hand.

STEAM TURBINES.

On account of the delay in obtaining the necessary data, the chapter on Steam Turbines will be found in the Appendix to this volume instead of following just here where it properly belongs.

Electric Power Transmission, Concluded.

ELECTRIC POWER TERMS

And Their Equivalents.

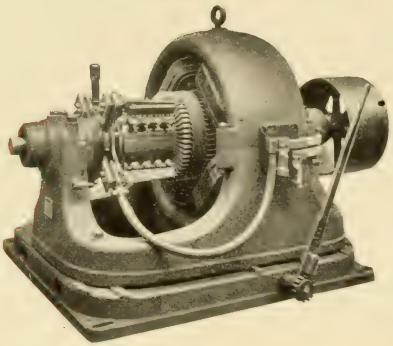
(Arranged for Convenient Reference by C. W. HUNT.)

One **Watt**	A RATE of doing work. 1. ampere per sec. at one volt. .7373 foot-pounds per second. 44 238 foot-pounds per minute. 2654.28 foot pounds per hour. .5027 mile-pounds per hour. .00134 Horse-Power. $\frac{1}{746}$ Horse-Power.
One **Kilowatt** (1000 watts)	A RATE of doing work. 737.3 foot-pounds per second. 44238. foot-pounds per minute. 502 7 mile-pounds per hour. 1.34 Horse-Power.
One **Horse-Power**	A RATE of doing work. 550. foot-pounds per second. 33000. foot-pounds per minute. 375. mile-pounds per hour. 746. watts. .746 kilowatt.
One **Watt-Hour**	A QUANTITY of work. 2654.28 foot-pounds. .503 mile-pounds. 1. ampere hour × one volt. .00134 Horse-Power Hour. $\frac{1}{746}$ Horse-Power Hour.
One **Horse-Power Hour**	A QUANTITY of work. 1,980,000. foot pounds. 375. mile-pounds. 746. watt-hour. .746 kilowatt-hour.
One **Ampere-Hour**	A QUANTITY of current. One ampere flowing for one hour, irrespective of the voltage. Watt-hour ÷ volts.
Torque	FORCE moving in a circle. A force of one pound at a radius of one foot.

MULTIPOLAR GENERATORS AND MOTORS,

(For Direct Current Lighting, Exciting, and Power Purposes.)

Westinghouse Belted Type.



(A 4-Pole Machine with Bed Plate.)

The design of multipolar direct current machines is characterized by a circular yoke, into which are solidly cast the pole pieces of laminated steel. This general type covers several styles of construction of frame, coils, armature, brush-holders and supports; the form of each, in a given case, being determined by the capacity, potential and speed of the machinery.

The smaller frames have a continuous yoke, the bearing stands being separable from the main casting.

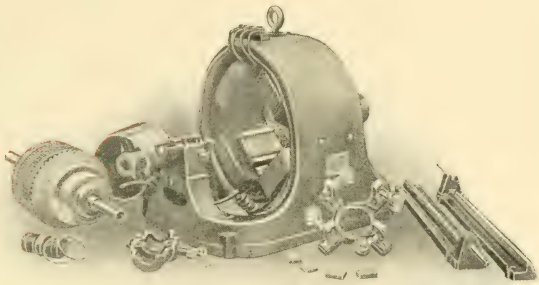
The medium and larger frames are divided in a horizontal plane, the bearing stands being integral with the lower casting. This method of construction, which is not suitable for small frames, presents numerous advantages for machines carrying armatures of too great weight to be readily placed or removed by hand.

Improved self-oiling, self-aligning ball-and-socket bearings are used on all machines. Terminals are mounted on top of those machines having continuous yokes, and on the sides of those having divided yokes.

The four-pole construction is used with machines of small or moderate capacity. In larger sizes, however, a better distribution of the elements of the machine is secured by the use of six poles.

These machines are supported either on rails or sliding

Westinghouse Belted Type, Continued.



(The parts of a 4-Pole Machine with rails ready for assembling.)

bases. Belt tension, in each case, is adjusted by moving the machine with a screw; a removable ratchet arm is furnished for this purpose with all the larger sizes.

Field Windings.—All multipolar field coils are machine-wound. Compound-wound machines have separately constructed shunt and series coils, the two coils going over the pole-piece side by side, and being removable at will. Any standard machine can be furnished with either shunt or compound field-winding, and slow-speed motors will be series-wound, when required.

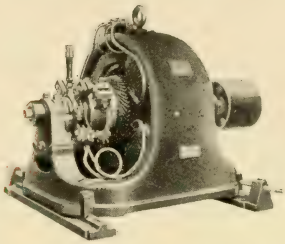
Armatures.—The armature cores are constructed from punched discs of special sheet steel carefully annealed in ovens before assembling. Longitudinal openings permit free passage of air through the core, and, where dimensions of the core and coils permit, the ventilation is augmented by ducts perpendicular to the axis of the core. When the machine is running, air is drawn in through the core and forcibly thrown from the ducts through the armature windings against the pole-pieces and field coils: thus the entire machine is maintained at an even, low temperature.

Three types of armature winding are employed, similar in that the coils are laid in slots in the core, but differing in the construction of the coils and methods of retaining.

For small machines, and for medium machines of higher potentials, we use machine-formed wire coils encased in insulating envelopes of prepared fullerboard and retained by surface bands.

Next in order of capacity is the bar-wound armature with

Westinghouse Belted Type, Continued.



(A 4-Pole Machine with rails.)

surface bands, the coils in this case being forged into shape before the insulation is applied.

The larger armatures also have forged bar coils, and they are retained by fibre wedges pressed into notches near the top of the slots in the core.

It will be noted that every coil is continuous throughout its length, with no joints except where it connects with the commutator. The method of winding employed is such that free circulation of air is permitted across the ends of the core through the coils

Brush-Holders.—Good commutation and freedom from sparking are to a marked extent dependent upon the brush-holder design. For machines of the higher potentials the sliding radial holder leaves nothing to be desired in this direction. Low potential machines demand a holder of very low resistance combined with extreme steadiness and quiet running. This service is attained by swivel holders, which carry heavy currents continuously without noise or undue heating.

A high grade carbon brush is used.

Rheostats.—A field rheostat accompanies each generator. The smaller rheostats are cylindrical in form, with ventilated cases of planished iron. For larger capacities a rectangular frame is used, the contacts being mounted directly upon the marble face-plate.

All rheostats are adapted either for wall mounting, or for switchboard mounting, with the body of the rheostat behind the board.

Motors are equipped with starting and automatic-releasing rheostats, whereby the machine is cut out of circuit at once should there be any interruption of the current, due to breaking of the line, opening of a circuit-breaker, or a shut down at the power-station. Injury to the motor, which would otherwise result upon restoration of the full line potential with the motor at a stand-still is thus avoided.

D. C. Multipolar Generators and Motors, Continued.

Westinghouse Belted Type, Continued.

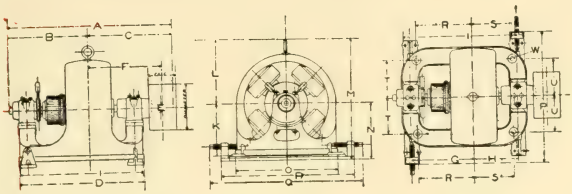


Diagram No. 1.
(Showing a 4-Pole Machine with rails.)

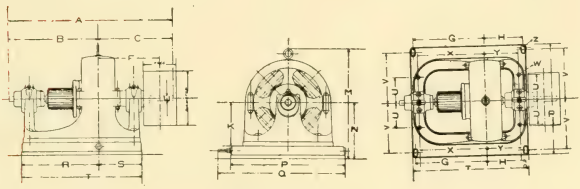


Diagram No. 2.
(Showing a 4-Pole Machine with bed plate)

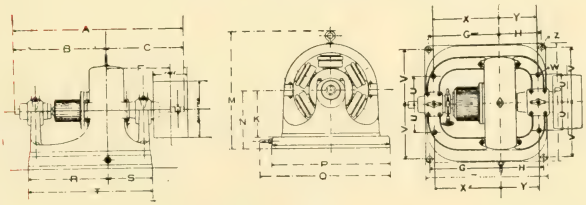


Diagram No. 3.
(Showing a 6-Pole Machine with bed plate.)

Note.—The following dimension tables that accompany the above diagrams are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

Table of Sizes and Approximate Dimensions in Inches of 4-Pole Machines with Rails.

(See Diagram No. 1, Page 869.)

Motors.	Generators.			Gen. 125 v.	Mots. 110-220 Volts. Gen. 250 Volts.	A—B+C									M—L+N										W	Pulley.			Key-Way in Shaft.	
H P	K.W.	Amp. 125 Volts.	Amp. 250 Volts.	Approximate. Revs.	Approximate. Revs.	B	C	D	E	F	G	H	I	K	L	N	O	P	Q	R	S	T	U	Dia. Bolt Hole.	Diam.	Face.	Length of Hub.	Width.	Depth.
$\frac{3}{4}$	.56	4.5	2.5	1400	1300	11	11	$16\frac{5}{16}$	$1\frac{15}{16}$	$9\frac{5}{8}$	$8\frac{1}{2}$	$5\frac{11}{16}$	$16\frac{7}{16}$	$7\frac{1}{4}$	$9\frac{1}{2}$	$8\frac{1}{4}$	$14\frac{3}{8}$	$20\frac{1}{4}$	23	$7\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{4}$	9	$\frac{1}{16}$	$3\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{32}$
1	.75	6	3	2000	1900	11	11	$16\frac{5}{16}$	$1\frac{15}{16}$	$9\frac{5}{8}$	$8\frac{1}{2}$	$5\frac{11}{16}$	$16\frac{7}{16}$	$7\frac{1}{4}$	$9\frac{1}{2}$	$8\frac{1}{4}$	$14\frac{3}{8}$	$20\frac{1}{4}$	23	$7\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{4}$	9	$\frac{1}{16}$	$3\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{32}$
2	1.50	12	6	1300	1200	$12\frac{1}{2}$	$13\frac{11}{16}$	$19\frac{1}{4}$	$1\frac{15}{16}$	$12\frac{5}{16}$	$9\frac{1}{2}$	$7\frac{1}{2}$	$19\frac{1}{4}$	$7\frac{3}{8}$	10	$8\frac{3}{4}$	$15\frac{1}{2}$	$20\frac{1}{4}$	$24\frac{1}{2}$	$8\frac{1}{2}$	$6\frac{1}{2}$	$5\frac{3}{4}$	$5\frac{3}{4}$	11	$\frac{1}{16}$	5	3	$2\frac{1}{2}$	$\frac{5}{16}$	$\frac{1}{8}$
$2\frac{1}{2}$	1.875	15	7.5	1800	1700	$12\frac{1}{2}$	$13\frac{11}{16}$	$19\frac{1}{4}$	$1\frac{15}{16}$	$12\frac{5}{16}$	$9\frac{1}{2}$	$7\frac{1}{2}$	$19\frac{1}{4}$	$7\frac{3}{8}$	10	$8\frac{3}{4}$	$15\frac{1}{2}$	$20\frac{1}{4}$	$24\frac{1}{2}$	$8\frac{1}{2}$	$6\frac{1}{2}$	$5\frac{3}{4}$	$5\frac{3}{4}$	11	$\frac{1}{16}$	5	3	$2\frac{1}{2}$	$\frac{5}{16}$	$\frac{1}{8}$
$3\frac{1}{2}$	2.62	21	10.5	1150	1050	$15\frac{1}{4}$	$16\frac{1}{4}$	$24\frac{5}{8}$	$1\frac{15}{16}$	$14\frac{3}{8}$	12	$8\frac{5}{8}$	$23\frac{5}{8}$	$9\frac{5}{8}$	12	$10\frac{3}{4}$	19	$25\frac{1}{2}$	$30\frac{1}{2}$	$10\frac{3}{4}$	$7\frac{5}{8}$	$6\frac{1}{2}$	$6\frac{1}{4}$	16	$\frac{1}{16}$	6	4	$3\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
5	3.75	30	15	1600	[1]1500	$15\frac{3}{4}$	$16\frac{1}{4}$	$24\frac{5}{8}$	$1\frac{15}{16}$	$14\frac{3}{8}$	12	$8\frac{5}{8}$	$23\frac{5}{8}$	$9\frac{5}{8}$	12	$10\frac{3}{4}$	19	$25\frac{1}{2}$	$30\frac{1}{2}$	$10\frac{3}{4}$	$7\frac{5}{8}$	$6\frac{1}{2}$	$6\frac{1}{4}$	16	$\frac{1}{16}$	6	4	$3\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
5	3.75	30	15	1000	950	$16\frac{3}{4}$	$19\frac{1}{4}$	$26\frac{5}{8}$	$1\frac{15}{16}$	$16\frac{3}{4}$	$12\frac{1}{2}$	$10\frac{1}{4}$	$25\frac{1}{2}$	$10\frac{1}{4}$	$12\frac{1}{2}$	$11\frac{5}{8}$	$20\frac{1}{4}$	$25\frac{1}{2}$	$31\frac{1}{4}$	$11\frac{1}{2}$	$9\frac{1}{4}$	$7\frac{3}{4}$	$7\frac{5}{16}$	16	$\frac{1}{16}$	8	5	$4\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
$7\frac{1}{2}$	5.62	45	22.5	1400	1350	$16\frac{3}{4}$	$19\frac{1}{4}$	$26\frac{5}{8}$	$1\frac{15}{16}$	$16\frac{3}{4}$	$12\frac{1}{2}$	$10\frac{1}{4}$	$25\frac{1}{2}$	$10\frac{1}{4}$	$12\frac{1}{2}$	$11\frac{5}{8}$	$20\frac{1}{4}$	$25\frac{1}{2}$	$31\frac{1}{4}$	$11\frac{1}{2}$	$9\frac{1}{4}$	$7\frac{3}{4}$	$7\frac{5}{16}$	16	$\frac{1}{16}$	8	5	$4\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
$7\frac{1}{2}$	5.62	45	22.5	875	850	$18\frac{5}{8}$	$19\frac{3}{4}$	$28\frac{1}{4}$	$1\frac{15}{16}$	17	14	$10\frac{3}{8}$	$28\frac{1}{4}$	$11\frac{1}{4}$	$13\frac{3}{4}$	$12\frac{7}{8}$	$22\frac{3}{8}$	30	$37\frac{1}{2}$	13	$9\frac{3}{8}$	8	8	13	$\frac{1}{16}$	8	5	$4\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
10	7.50	60	30	1300	1250	$18\frac{5}{8}$	$19\frac{3}{4}$	$28\frac{1}{4}$	$1\frac{15}{16}$	17	14	$10\frac{3}{8}$	$28\frac{1}{4}$	$11\frac{1}{4}$	$13\frac{3}{4}$	$12\frac{7}{8}$	$22\frac{3}{8}$	30	$37\frac{1}{2}$	13	$9\frac{3}{8}$	8	8	13	$\frac{1}{16}$	8	5	$4\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
10	7.50	60	30	775	750	$19\frac{1}{4}$	$21\frac{5}{8}$	$30\frac{5}{8}$	$1\frac{15}{16}$	$18\frac{3}{4}$	$14\frac{1}{2}$	$11\frac{5}{8}$	$29\frac{3}{8}$	$12\frac{1}{8}$	$15\frac{1}{4}$	$14\frac{1}{4}$	$25\frac{1}{4}$	35	$39\frac{1}{2}$	$13\frac{1}{2}$	$10\frac{1}{4}$	$8\frac{5}{16}$	$8\frac{3}{4}$	13	$\frac{1}{16}$	9	6	$5\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
15	11.25	90	45	1200	1150	$19\frac{1}{4}$	$21\frac{5}{8}$	$30\frac{5}{8}$	$1\frac{15}{16}$	$18\frac{3}{4}$	$14\frac{5}{8}$	$11\frac{5}{8}$	$29\frac{3}{8}$	$12\frac{1}{8}$	$15\frac{1}{4}$	$14\frac{3}{4}$	$25\frac{1}{4}$	35	$39\frac{1}{2}$	$13\frac{1}{2}$	$10\frac{1}{4}$	$8\frac{5}{16}$	$8\frac{3}{4}$	13	$\frac{1}{16}$	9	6	$5\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
15	11.25	90	45	700	650	$20\frac{3}{4}$	$23\frac{5}{8}$	$32\frac{5}{8}$	$1\frac{15}{16}$	20	$16\frac{1}{2}$	$11\frac{5}{8}$	$32\frac{1}{4}$	$13\frac{3}{4}$	17	$15\frac{1}{4}$	$27\frac{5}{8}$	35	$41\frac{1}{2}$	$15\frac{1}{4}$	11	$9\frac{1}{4}$	$9\frac{5}{8}$	16	$\frac{1}{16}$	14	7	$5\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
20	15.	120	60	1050	1050	$20\frac{3}{4}$	$23\frac{5}{8}$	$32\frac{5}{8}$	$1\frac{15}{16}$	20	$16\frac{1}{2}$	$11\frac{5}{8}$	$32\frac{1}{4}$	$13\frac{3}{4}$	17	$15\frac{1}{4}$	$27\frac{5}{8}$	35	$41\frac{1}{2}$	$15\frac{1}{4}$	11	$9\frac{1}{4}$	$9\frac{5}{8}$	16	$\frac{1}{16}$	14	7	$5\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
20	15.	120	60	600	600	$25\frac{1}{4}$	$25\frac{3}{8}$	$37\frac{3}{8}$	$2\frac{1}{4}$	22	$19\frac{5}{8}$	$13\frac{1}{4}$	$37\frac{3}{8}$	$15\frac{5}{8}$	$18\frac{7}{8}$	$17\frac{1}{2}$	$31\frac{3}{4}$	$40\frac{1}{2}$	$50\frac{1}{4}$	$18\frac{5}{8}$	$12\frac{3}{4}$	11	11	16	$\frac{1}{16}$	14	8	$6\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
30	22.5	180	90	975	975	$25\frac{1}{4}$	$25\frac{3}{8}$	$37\frac{3}{8}$	$2\frac{1}{4}$	22	$19\frac{5}{8}$	$13\frac{1}{4}$	$37\frac{3}{8}$	$15\frac{5}{8}$	$18\frac{7}{8}$	$17\frac{1}{2}$	$31\frac{3}{4}$	$40\frac{1}{2}$	$50\frac{1}{4}$	$18\frac{5}{8}$	$12\frac{3}{4}$	11	11	16	$\frac{1}{16}$	14	8	$6\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
30	22.5	180	90	600	575	$26\frac{1}{2}$	$29\frac{1}{4}$	42	$2\frac{3}{8}$	$26\frac{1}{4}$	21	$15\frac{3}{4}$	$41\frac{1}{4}$	$17\frac{3}{4}$	$21\frac{7}{8}$	$19\frac{5}{8}$	$36\frac{1}{8}$	$46\frac{1}{2}$	$58\frac{3}{8}$	20	$14\frac{1}{2}$	$12\frac{1}{2}$	$12\frac{1}{2}$	16	$\frac{1}{16}$	15	11	7	$\frac{5}{16}$	$\frac{1}{8}$
40	30.	240	120	950	950	$25\frac{5}{8}$	$28\frac{5}{8}$	$39\frac{7}{8}$	$2\frac{3}{8}$	$24\frac{5}{8}$	$20\frac{1}{4}$	$14\frac{5}{8}$	$39\frac{1}{4}$	17	$21\frac{5}{8}$	$18\frac{13}{16}$	$34\frac{1}{8}$	$46\frac{1}{2}$	$52\frac{5}{8}$	$18\frac{3}{4}$	$13\frac{3}{4}$	$11\frac{3}{4}$	$11\frac{3}{4}$	16	$\frac{1}{16}$	15	11	7	$\frac{5}{16}$	$\frac{1}{8}$
40	30.	240	120	550	550	$34\frac{3}{8}$	$30\frac{3}{4}$	$47\frac{1}{4}$	$2\frac{3}{8}$	$26\frac{1}{4}$	$20\frac{1}{8}$	$15\frac{5}{8}$	$46\frac{1}{4}$	$18\frac{5}{8}$	$23\frac{3}{8}$	$20\frac{1}{4}$	$37\frac{3}{8}$	$46\frac{1}{2}$	$55\frac{5}{8}$	$25\frac{1}{4}$	$15\frac{3}{4}$	12	12	16	$\frac{1}{16}$	20	11	8	$\frac{3}{8}$	$\frac{3}{16}$
[2]50	37.5		150		900	$26\frac{5}{8}$	$29\frac{1}{4}$	42	$2\frac{3}{8}$	$26\frac{1}{4}$	21	$15\frac{3}{4}$	$41\frac{1}{4}$	$17\frac{3}{4}$	$21\frac{7}{8}$	$19\frac{5}{8}$	$36\frac{1}{8}$	$46\frac{1}{2}$	$58\frac{3}{8}$	20	$14\frac{1}{2}$	$12\frac{1}{2}$	$12\frac{1}{2}$	16	$\frac{1}{16}$	15	11	7	$\frac{5}{16}$	$\frac{1}{8}$
[3]50	37.5	300			900	$29\frac{1}{4}$	$29\frac{1}{4}$	$44\frac{1}{4}$	$2\frac{3}{8}$	$26\frac{1}{4}$	$26\frac{1}{4}$	$15\frac{3}{4}$	$43\frac{1}{4}$	$17\frac{3}{4}$	$21\frac{7}{8}$	$19\frac{5}{8}$	$36\frac{1}{8}$	$46\frac{1}{2}$	$54\frac{3}{8}$	$22\frac{1}{4}$	$14\frac{1}{2}$	$12\frac{1}{2}$	$12\frac{1}{2}$	16	$\frac{1}{16}$	15	11	7	$\frac{5}{16}$	$\frac{1}{8}$
50	37.5	300	150	550	550	$33\frac{3}{4}$	$32\frac{1}{4}$	$47\frac{5}{8}$	$2\frac{5}{8}$	$28\frac{1}{4}$	$25\frac{3}{8}$	$16\frac{5}{8}$	$46\frac{3}{4}$	19	$23\frac{1}{2}$	$20\frac{7}{8}$	$38\frac{3}{4}$	$46\frac{1}{2}$	$55\frac{1}{4}$	$24\frac{3}{8}$	$15\frac{3}{4}$	13	13	20	$\frac{1}{16}$	20	11	8	$\frac{1}{2}$	$\frac{1}{16}$
60	45.	360	180	850	850	$34\frac{7}{8}$	$30\frac{3}{4}$	$47\frac{1}{4}$	$2\frac{5}{8}$	$26\frac{1}{2}$	$26\frac{1}{2}$	$15\frac{5}{8}$	$46\frac{1}{4}$	$18\frac{1}{2}$	$23\frac{3}{8}$	$20\frac{1}{4}$	$37\frac{1}{2}$	$46\frac{1}{2}$	$55\frac{5}{8}$	$25\frac{1}{4}$	$15\frac{3}{4}$	12	12	20	$\frac{1}{16}$	20	11	8	$\frac{3}{8}$	$\frac{3}{16}$
[4]75	56.25		225		800	$33\frac{1}{4}$	$32\frac{1}{4}$	$47\frac{5}{8}$	$2\frac{5}{8}$	$28\frac{1}{4}$	$25\frac{3}{8}$	$16\frac{5}{8}$	$46\frac{3}{4}$	19	$23\frac{1}{2}$	$20\frac{7}{8}$	$38\frac{3}{4}$	$46\frac{1}{2}$	$55\frac{1}{4}$	$24\frac{3}{8}$	$15\frac{3}{4}$	13	13	20	$\frac{1}{16}$	20	11	8	$\frac{1}{2}$	$\frac{1}{16}$

1. Speed of 250 volt Generator is 1600.
2. See next line for 125 volt Generator and 110 volt Motor.
3. 125 volt Generator and 110 volt Motor *only*.
4. See page 14 for 75 hp 110 volt Motor.

Table of Sizes and Approximate Dimensions in Inches of 4-Pole Machines with Bed Plates

(See Diagram 2, page 869.)

Motors.	Generators.			Mot. 110 V. Gen. 125 V.	Mots. 110, 220 & 500 volts and Gen. 250v.	A=B+C								T=R+S					W	Z	Pulley.			Key-Way in Shaft.	
	K W	Amp. 125 Volts.	Amp. 250 Volts.	Approximate.		B	C	E	F	G	H	K	M	N	P	R	S	V	Dia. Bolt Hole in field casting	Width of Bolt Hole in bed-plate.	Diam.	Face.	Length of Hub.	Width.	Depth.
H P				Revs	Revs.																				
75	56.25	450		800		38 1/4	32 1/8	2 5/8	27 5/8	31 3/4	19 1/2	19	47 1/2	24	49 3/4	33	20 3/8	22 5/8	1 5/8	1 1/4	20	11	8	5/8	5/16
75	56.25	450		525		42 1/16	34 1/16	2 5/8	29 1/2	35 5/8	19 5/8	21	52	27	55	37 1/8	20 5/8	25 1/8	1 5/8	1 1/4	26	12	9	3/4	5/16
75	56.25		225		525	35 1/16	34 3/16	2 5/8	29 1/2	29 1/8	19 5/8	21	52	27	55	30 5/8	20 5/8	25 1/8	1 5/8	1 1/4	26	12	9	3/4	5/16
100	75	600		750		42 1/16	34 1/16	2 5/8	29 1/2	35 5/8	19 5/8	21	52	27	55	37 1/8	20 5/8	25 1/8	1 5/8	1 1/4	26	14	9	1	5/16
100	75		300		750	35 1/16	34 3/16	2 5/8	29 1/2	29 1/8	19 5/8	21	52	27	55	30 5/8	20 5/8	25 1/8	1 5/8	1 1/4	26	14	9	1	5/16

Table of Sizes and Approximate Dimensions in Inches of 125 Volt, 6 Pole Generators.

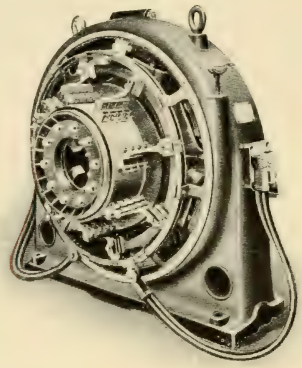
(See Diagram No 3, page 869.)

K.W.	Amp.	R.P.M.	A=B+C							T=R+S						W Diam. of Bolt Hole in bed-plate.	Z Width of Bolt Hole in bed-plate.	Pulley.			Key-Way in Shaft.	
			B	C	E	F	G	H	K	M	N	P	R	S	V			Diam.	Face.	Length of Hub.	Width.	Depth.
100	800	550	47 11/16	39 7/8	3 7/8	34 7/8	36 7/16	21 7/8	24	61 1/8	30	61	38 7/16	23 7/8	28 1/8	1 1/4	1 1/2	28	16	8	3/4	3/8
150	1200	475	57 3/8	48	4 3/8	39	45 3/8	22 3/8	29	70 1/4	35	75 1/8	48 3/8	25 3/8	34 1/4	1 1/4	1 1/2	34	26	16	1	3/8

250 Volt, 6 Pole Generators.

100	400	550	43 7/8	39 7/8	3 7/8	34 7/8	32 5/8	21 7/8	24	61 1/8	30	61	34 5/8	23 7/8	28 1/8	1 1/4	1 1/2	28	16	8	3/4	3/8
150	600	550	48 3/8	48 1/4	4 1/4	39	36 3/8	23 1/8	29	70 1/4	35	75 1/8	38 7/8	25 3/8	34 5/8	1 1/4	1 1/2	34	26	16	1	3/8
200	800	450	56 3/4	59 1/4	5 1/8	47 1/2	47 3/8	26 5/8	32 1/2	78	38 1/2	82	49 5/8	29 1/2	38 1/2	1 1/4	1 1/2	45	33	18	1 5/16	1/2

D. C. Multipolar Generators, Continued.



Westinghouse Engine Type.

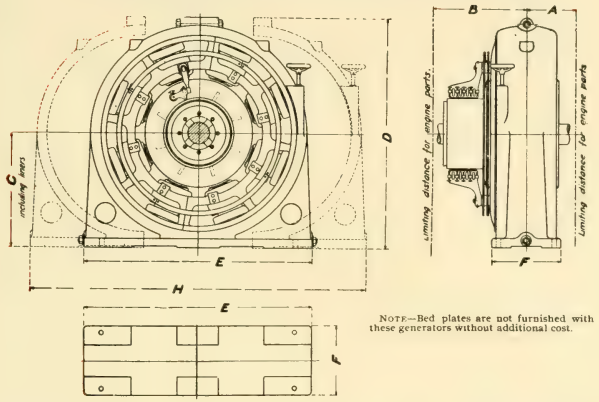
The general design of these well known engine type generators consists of a circular yoke carrying inwardly projecting pole pieces of laminated soft steel. The field castings are divided vertically, affording excellent facility for the inspection or the removal of the armature or field coils, without the necessity of removing the outboard bearing or dismantling the engine. Machines are also built with horizontally split fields, which is of great convenience where head room is limited, and cranes or other devices for handling heavy castings are not available.

The fields, armatures, commutators, etc., are of the same general construction as those for the belted type machines described in the preceding pages.

The brush-holder mechanism is carried by brackets projecting from a ring, concentric with and supported by the field. A hand-wheel rocker arrangement accomplishes the adjustment of all the brushes simultaneously. It will be noted that the supporting ring carrying the brush-holder rods lies close to the fields, and does not project over the commutator.

In this book we furnish only a table of 125-volt generators with vertically split frames, up to and including 160 K. W. in capacity. These machines are also made, however, of 250 and 500 volts, with both vertically and horizontally split frames, and of as high capacity as 600 K. W. for 125-volt machines, and much greater capacity for the machines of higher voltage.

Westinghouse Engine Type, Concluded.



NOTE—Bed plates are not furnished with these generators without additional cost.

K. W.	Amperes at 125 Volts.	Number of Poles.	R. P. M.	A	B	C	D	E	F	H
*5¾	46	6	400–425	7	8½	11¾	25¾	24	14	.....
*10	80	6	375–400	7¾	12¼	16⅝	32¾	34	12½	.....
17½	140	6	375–400	9	15½	19½	39¾	37½	14	59½
17½	140	6	325–350	9	15½	19½	39¼	37½	14	59½
25	200	6	320–350	10	20	21¾	43½	41½	15½	61½
25	200	6	300–320	10	20	21¾	43½	41½	15½	61½
25	200	6	275–300	10½	19¼	21¾	43½	41½	15½	61½
37½	300	6	290–320	10½	20	24	47¾	46	16½	68
37½	300	6	280–300	10½	20	24	47¾	46	16½	68
50	400	6	275–300	11	21¾	25¾	51½	50½	17½	76½
50	400	6	330–350	10½	22½	24	47¾	46	16½	68
50	400	6	265–290	11	21¾	25¾	51½	50½	17½	76½
62½	500	6	275–300	12	23½	27¼	54½	54	19	82
62½	500	6	250–275	12	23½	27¼	54½	54	19	82
62½	500	8	100–110	13½	26	33½	67½	66½	22½	103½
75	600	6	265–290	12½	27	29¼	58¾	57¼	20½	89¼
75	600	6	250–275	12½	27	29¾	58¾	57¾	20½	89¾
90	720	8	160–175	13½	27	33½	67½	66½	22½	103½
100	800	8	250–275	12¾	28	33½	67¼	66½	20	102½
100	800	8	230–250	12¾	27	33½	67¼	66½	20	102½
125	1000	8	280–300	12¼	28½	33½	67¾	66½	20	102½
125	1000	8	200–220	13½	30	33½	67½	66½	22½	103½
140	1120	8	225–240	13½	30	33½	67½	66½	22½	103½
150	1200	8	250–260	13½	30	33½	67½	66½	22½	103½
160	1280	8	310–330	13½	30	33½	67½	66½	22½	103½

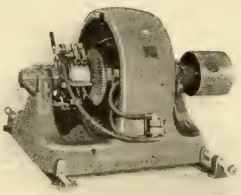
Those in heavy face type are standard machines and are carried in stock; other machines referred to in this table are built only on order.

*5¾ and 10 K. W. fields are not parted.

Note.—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for the purposes of installation.

D. C. Multipolar Generators and Motors, Continued.

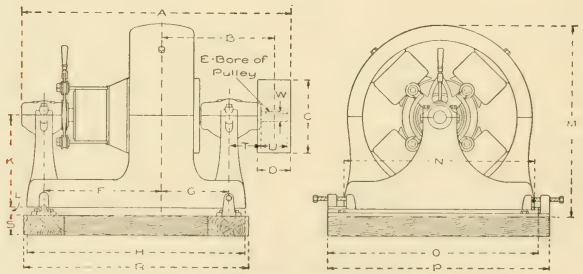
General Electric Belted Type.



The four-pole construction of these machines allows an economical distribution of the magnetic material, and by shortening the magnetic circuits the exciting current is reduced and an improvement in efficiency effected.

The machines occupy very small floor space Special attention has been given to securing a strong and rigid yet graceful frame of the smallest dimensions consistent with stability. The mechanical construction of bearings, shaft, and oiling devices is such as to make operation safe and easy, even in the hands of unskilled attendants.

The comparatively low belt speed saves wear and tear of belts and bearings, and practically eliminates noise.



Form H Dimension Diagram.

After running continuously for ten hours at rated full load, the rise in temperature above the surrounding air will not exceed 40°C. in the armature or 45°C. in the commutator. The generator will operate for one hour at 25% overload, and will not be injured by a momentary overload of 50%.

General Electric Belted Type, Concluded.

Table of Sizes and Approximate Dimensions in Inches of 4-Pole Machines.

(See Diagram on opposite page)

(Slow Speed Machines.)

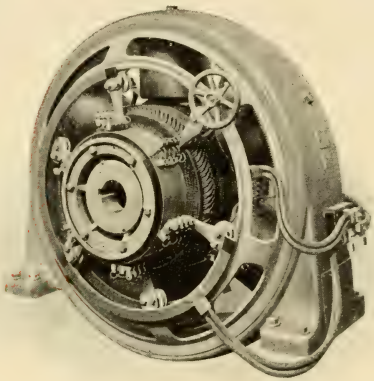
Classification.						Pulley.										O	W'd Base Frame.			Key-Way.
K. W.	Speed.	Volts Full Load	Amperes Full Load.	A	B	C	D	E	F	G	H	K	L	M	N	Length of Rails.	P	R	S	
9	1450	125-250-500	72- 36 -18	$38\frac{3}{16}$	$16\frac{1}{8}$	$9\frac{1}{2}$	$4\frac{3}{4}$	$1\frac{3}{8}$	$16\frac{1}{2}$	$10\frac{3}{4}$	$31\frac{3}{4}$	12	$1\frac{3}{4}$	$25\frac{3}{8}$	26	$34\frac{3}{4}$	$36\frac{1}{8}$	$34\frac{1}{4}$	3	3 x $\frac{3}{8}$ x $\frac{3}{16}$
12.5	1350	125-250-500	100- 50- 25	$42\frac{5}{8}$	$18\frac{3}{8}$	10	$6\frac{1}{2}$	$1\frac{3}{4}$	$17\frac{1}{4}$	$11\frac{3}{4}$	$34\frac{1}{2}$	$13\frac{7}{8}$	$1\frac{1}{2}$	$29\frac{1}{4}$	30	39	$40\frac{1}{2}$	36	3	$3\frac{3}{4}$ x $\frac{1}{2}$ x $\frac{1}{4}$
17.5	1175	125-250-500	140- 70- 35	$49\frac{5}{8}$	$21\frac{5}{8}$	$11\frac{1}{2}$	$8\frac{3}{4}$	2	$19\frac{5}{8}$	$13\frac{3}{8}$	39	$15\frac{1}{2}$	$1\frac{1}{2}$	$32\frac{1}{2}$	33	$4\frac{1}{2}$	$43\frac{1}{2}$	40	3	$5\frac{1}{4}$ x $\frac{1}{2}$ x $\frac{1}{4}$
25	1100	125-250-500	200-100- 50	$56\frac{5}{8}$	25	$12\frac{1}{2}$	9	$2\frac{1}{8}$	$22\frac{1}{4}$	$15\frac{1}{4}$	$44\frac{1}{4}$	$16\frac{3}{4}$	$1\frac{1}{2}$	35	36	$44\frac{1}{2}$	$46\frac{1}{4}$	$44\frac{1}{4}$	3	$6\frac{1}{16}$ x $\frac{1}{2}$ x $\frac{1}{4}$
30	1050	125-250-500	240-120- 60	$60\frac{3}{4}$	$26\frac{1}{4}$	13	11	$2\frac{1}{4}$	$22\frac{3}{4}$	$15\frac{3}{4}$	$45\frac{1}{2}$	$18\frac{1}{2}$	$1\frac{5}{8}$	$38\frac{5}{8}$	40	52	53	$48\frac{1}{2}$	4	$6\frac{1}{4}$ x $\frac{1}{2}$ x $\frac{1}{4}$
45	975	125-250-500	360-180- 90	$68\frac{3}{4}$	$29\frac{7}{8}$	$16\frac{3}{4}$	13	$2\frac{3}{4}$	$26\frac{3}{8}$	$18\frac{3}{4}$	$52\frac{3}{4}$	$22\frac{1}{2}$	$1\frac{5}{8}$	$46\frac{1}{4}$	$46\frac{1}{2}$	55	$58\frac{3}{4}$	$54\frac{3}{8}$	4	8 x $\frac{5}{8}$ x $\frac{5}{16}$
55	925	125-250-500	440-220-110	$72\frac{1}{8}$	$32\frac{1}{8}$	$17\frac{3}{4}$	$16\frac{3}{4}$	$3\frac{1}{4}$	$25\frac{7}{8}$	$18\frac{3}{4}$	$52\frac{7}{8}$	24	$1\frac{5}{8}$	49	$50\frac{3}{4}$	$60\frac{1}{4}$	63	$54\frac{3}{8}$	6	11 x $\frac{3}{4}$ x $\frac{3}{8}$
65	875	125-250-500	520-260-130	$79\frac{5}{8}$	$33\frac{5}{8}$	$18\frac{3}{4}$	$19\frac{3}{8}$	$3\frac{1}{4}$	$29\frac{3}{4}$	$18\frac{5}{8}$	$57\frac{5}{8}$	25	$1\frac{3}{4}$	$51\frac{3}{4}$	53	$62\frac{3}{4}$	$65\frac{3}{4}$	$58\frac{3}{8}$	6	$12\frac{1}{4}$ x $\frac{3}{4}$ x $\frac{3}{8}$
85	750	125-250-500	680-340-170	$91\frac{3}{4}$	39	$21\frac{3}{4}$	24	$3\frac{3}{4}$	$34\frac{1}{4}$	$19\frac{3}{4}$	$63\frac{1}{2}$	27	2	56	56	$65\frac{1}{2}$	$68\frac{1}{4}$	64	6	$16\frac{1}{4}$ x 1 x $\frac{1}{2}$
(Moderate Speed Machines.)																				
6.5	950	125-250-500	52- 26- 13	$37\frac{15}{16}$	$16\frac{1}{8}$	11	$4\frac{1}{4}$	$1\frac{3}{8}$	$16\frac{1}{2}$	$10\frac{3}{4}$	$31\frac{3}{4}$	12	$1\frac{3}{8}$	$25\frac{3}{8}$	26	$34\frac{3}{4}$	$36\frac{1}{8}$	$34\frac{1}{4}$	3	3 x $\frac{3}{8}$ x $\frac{3}{16}$
9	900	125-250-500	72- 36- 18	$42\frac{5}{8}$	$18\frac{3}{8}$	$11\frac{1}{2}$	$6\frac{1}{2}$	$1\frac{3}{4}$	$17\frac{1}{4}$	$11\frac{3}{4}$	$34\frac{1}{2}$	$13\frac{7}{8}$	$1\frac{1}{2}$	$29\frac{1}{4}$	30	39	$40\frac{1}{2}$	36	3	$3\frac{3}{4}$ x $\frac{1}{2}$ x $\frac{1}{4}$
13.5	850	125-250-500	108- 54- 27	$49\frac{1}{2}$	$21\frac{3}{8}$	$12\frac{1}{4}$	$8\frac{1}{2}$	2	$19\frac{5}{8}$	$13\frac{1}{4}$	39	$15\frac{1}{2}$	$1\frac{1}{2}$	$32\frac{1}{2}$	33	$43\frac{1}{2}$	$43\frac{1}{2}$	40	3	$5\frac{1}{4}$ x $\frac{1}{2}$ x $\frac{1}{4}$
17	750	125-250-500	136- 68- 34	$56\frac{5}{8}$	25	$13\frac{3}{4}$	$8\frac{1}{2}$	$2\frac{1}{8}$	$22\frac{1}{4}$	$15\frac{1}{4}$	$44\frac{1}{4}$	$16\frac{3}{4}$	$1\frac{1}{2}$	35	36	$44\frac{1}{2}$	$46\frac{1}{4}$	$44\frac{1}{4}$	3	$6\frac{1}{16}$ x $\frac{1}{2}$ x $\frac{1}{4}$
20	700	125-250-500	160- 80- 40	$60\frac{1}{4}$	$26\frac{1}{4}$	15	$10\frac{1}{2}$	$2\frac{1}{4}$	$22\frac{3}{4}$	$15\frac{3}{4}$	$45\frac{1}{2}$	$18\frac{1}{2}$	$1\frac{5}{8}$	$38\frac{5}{8}$	40	52	53	$48\frac{1}{2}$	4	$6\frac{1}{8}$ x $\frac{1}{2}$ x $\frac{1}{4}$
30	675	125-250-500	240-120- 60	$67\frac{3}{4}$	$29\frac{1}{4}$	$20\frac{1}{4}$	11	$2\frac{1}{4}$	$26\frac{3}{8}$	$18\frac{3}{8}$	$52\frac{3}{4}$	$22\frac{1}{2}$	$1\frac{5}{8}$	$46\frac{1}{4}$	$46\frac{1}{2}$	55	$58\frac{3}{4}$	$54\frac{3}{8}$	4	8 x $\frac{5}{8}$ x $\frac{5}{16}$
40	605	125-250-500	320-160- 80	$71\frac{5}{8}$	$32\frac{1}{4}$	$22\frac{3}{4}$	$15\frac{1}{2}$	$3\frac{1}{8}$	$25\frac{5}{8}$	$18\frac{1}{2}$	$52\frac{5}{8}$	24	$1\frac{5}{8}$	49	$50\frac{3}{4}$	$60\frac{1}{2}$	63	$54\frac{3}{8}$	6	11 x $\frac{3}{4}$ x $\frac{3}{8}$
50	600	125-250-500	400-200-100	$78\frac{5}{8}$	$33\frac{1}{4}$	23	$18\frac{1}{2}$	$3\frac{1}{4}$	$29\frac{3}{4}$	$18\frac{5}{8}$	$57\frac{5}{8}$	25	$1\frac{3}{4}$	$51\frac{3}{4}$	53	$62\frac{3}{4}$	$65\frac{3}{4}$	$58\frac{3}{8}$	6	$12\frac{1}{4}$ x $\frac{3}{4}$ x $\frac{3}{8}$
75	550	125-250-500	600-300-150	92	39	25	$24\frac{1}{2}$	$3\frac{3}{8}$	$34\frac{1}{4}$	$19\frac{3}{4}$	$63\frac{1}{2}$	27	2	56	56	$65\frac{1}{2}$	$68\frac{1}{4}$	64	6	$16\frac{1}{4}$ x 1 x $\frac{1}{2}$

Note.—It will be observed that the moderate speed machines are practically the same as the slow speed machines, except that they are adapted to higher speeds by being provided with special armatures and pulleys, and in some cases special field windings.

These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

D. C. Multipolar Generators, Continued.

General Electric Engine Type.



Front View of Form L Generator.

The performance of these machines is as follows:

The temperature of no part of the armature or field coils, as measured by the thermometer, after a run of 24 hours at rated amperes and rated volts, with normal conditions of ventilation, will rise more than 35°C. or the commutator more than 40°C above that of the air surrounding the machine, provided the temperature of the air does not exceed 25°C. With the load then increased to 50% above the rated amperes, and at rated volts (50% overload) for two hours, the accumulated temperature of no part of the generator will be more than 55°C. above that of the surrounding air.

In the event of the temperature of the surrounding air differing from 25°C., the above rise in temperature is to be corrected ½% for each degree C. that the temperature of the surrounding air differs from 25°C.

The generator will carry an overload in current of 50% at rated volts for two hours without movement of brushes, and 100% overload at rated volts, momentarily, without injurious sparking.

D. C. Multipolar Generators, Continued.

General Electric Engine Type, Continued.

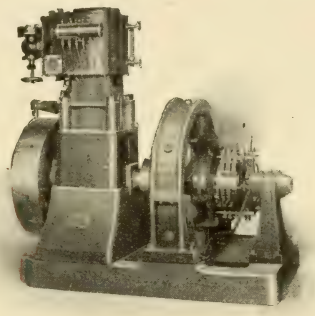
Table of Sizes and Approximate Dimensions, of Form L Machine in Inches.

Note.—These tables are to be used for estimating purposes only. Detailed drawings should be obtained in each case from the builder for purposes of installation.

Classification.			Min'm Speed With Special Yoke.		Output at Brushes.		Approximate Brake H. P. to Drive.	A	B	C	D	E	F	G	H	K	L	M	N	O	P	R
Poles	K W.	Speed.	125 Volts.	250 Volts.	Amperes.	Volts.																
6	25	395	265	275	200	125	37	24	40	17	23	7½	22	3⅜	9¼	24½	19½	4,	4½	18	3⅜	16½	12¼
6	35	300	260	270	280	125	52	26	41¾	17	24¾	7½	24	3⅜	11	27½	22½	4,	5⅛	18	3⅜	11¾	12¼
6	50	280	235	245	400	125	75	26½	45⅞	20	25⅞	9	24	3⅜	13½	30⅜	24½	4½,	6½	21	3¾	12⅞	14½
6	75	270	225	235	600	125	112	33	51¾	23	31¾	9½	31½	3⅜	11½	31⅞	26	5½,	7½	24	4⅜	12¾	15½
6	100	270	225	235	800	125	150	35½	58	24	34	9½	31½	3⅜	14⅝	37¾	30½	6,	8½	24	4⅜	14	16¾
8	100	230	200	205	1280	125	240	42¼	66½	26	40⅜	10	45⅛	4⅜	16	41⅛	33⅛	7,	10	27	4⅜	14¾	19
8	150	230	135	140	1280	125	240	48	79	32	47	11	45⅞	4⅜	18¾	53¾	41¼	7,	10	33	7⅛	17½	25½
8	200	200	180	185	1600	125	300	48	79	32	47	11	45⅞	4⅜	17½	59	46½	8,	11	33	7⅛	17½	28½
8	200	160	135	140	1600	125	300	56	85	32	53	12	53	5⅜	20	61	59½	8,	11	33	7⅛	18¾	28½

D. C. Multipolar Generators, Continued.

General Electric Small Direct-Coupled Generating Sets.



G. E. MP 6-30-305 With G. E. Single Cylinder Engine.

An inspection of the above illustration shows the freedom from complication in design or multiplicity of parts.

On the single cylinder engines, only one valve is used and it is driven directly from the eccentric pin of the governor by means of a valve rod.

The bed is carried out to the full width of the generator frame, making an ample base surface for foundation, without increasing the floor space required.

G. E. Vertical Single Cylinder Open Type Engines and Multipolar Generators.

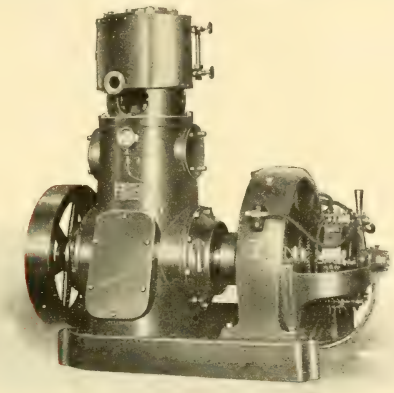
(With Ironclad Armatures.)

Classification. Type.	Poles.	K. W.	Speed.	Volts Full Load.	Amperes Full Load.	Floor Space.	Height.	Diameter Steam Pipe.	Diameter Exhaust Pipe.	Diameter Cylinder.	Stroke.
MP	4-	2½-	700	110	23	39″ x 23″	32½″	¾″	1″	3½″	3″
MP	4-	4 -	600	110	36	52″ x 27″	41″	1″	1½″	4½″	4″
MP	6-	7 -	550	110	64	50″ x 30″	46″	1¼″	1½″	5″	4½″
MP	6-	10 -	450	110	91	57″ x 34″	51″	1½″	2″	6½″	5″
MP	6-	15 -	400	110	136	62″ x 37″	60″	2″	2½″	8″	6″
MP	6-	20 -	360	125	160	75″ x 48″	68½″	2½″	3″	9″	7″
MP	6-	30 -	305	125	240	80″ x 48″	76″	3″	3½″	11″	8″

Ratings of sets with single-engines based on 80 lbs. steam, non-condensing.

G. E. Vertical Single Cylinder Enclosed Type Engines and Multipolar Generators.
(With Ironclad Armatures.)

The marked success which has attended the use of enclosed engines having automatic forced lubrication, has led to the adoption of this feature in connection with the single cylinder engines. All of the moving parts are enclosed by the engine column, allowing perfect lubrication and reducing



G. E. MP 6-15-400 Generator and G. E. Single Cylinder Engine.

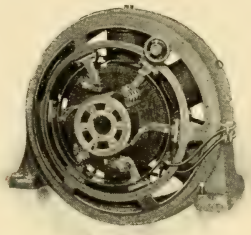
wear and attention to a minimum. The cylinder is separated from the column, giving access to the stuffing boxes when the engine is in operation, and water is not allowed to mix with the oil. The general construction of these engines is similar to that of the open type.

Classification. Type. Poles. Kw. Speed.	Volts Full Load.	Amperes Full Load.	Floor Space.	Height.	Diameter Steam Pipe.	Diameter Exhaust Pipe.	Diameter Cylinder.	Stroke.
MP 6- 7-550	110	64	47″ x 30″	50½″	1¼″	1½″	5″	4½″
MP 6-10-450	110	91	54″ x 34″	56½″	1½″	2″	6½″	5″
MP 6-15-400	110	136	65″ x 38″	64″	2″	2½″	8″	6″
MP 8-20-360	110	182	65″ x 42″	71½″	2½″	3″	9″	7″
MP 6-50-280	125	400	98″ x 55″	99″	3½″	4″	12″	11″

Ratings of sets with single cylinder engines based on 80 lbs. steam, non-condensing.

D. C. Multipolar Generators, Concluded.

G. E. Small Direct-Coupled Generating Sets, Concluded.



(Front View of G. E. Engine Type Multipolar Generator Such as is Used in Generating Sets.)

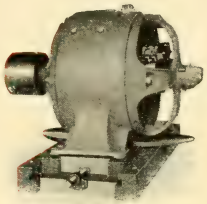
G. E. Vertical Tandem Compound Engines and Multipolar Generators.
(With Ironclad Armatures.)

Where high pressure steam is available and economy of operation a very essential consideration, these sets with tandem compound engines are recommended on account of their high efficiency. The general construction of these sets is the same as that of the single cylinder type and they present the same desirable features, viz.: Simplicity, compactness, stability, and durability. Special attention has been given to the oiling system for the sets with compound engines. All the bearings are oiled automatically under pressure so that the labor is reduced to a minimum and perfect lubrication is insured at all times.

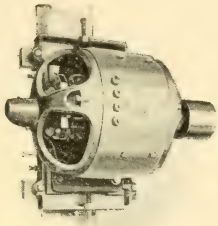
Classification. Type.	Poles.	K. W.	Speed.	Volts Full Load.	Amperes Full Load.	Floor Space.	Height.	Diameter. Steam Pipe.	Diameter Exhaust Pipe.	Diameter Cylinder	Stroke.
MP 6–25–450			125	200		73″ x 45½″	64½″	2 ″	3 ″	6½″ & 10½″	5″
MP 6–35–400			125	280		88″ x 51 ″	76 ″	2 ″	3½″	7½″ & 12½″	6″
MP 6–50–400			125	400		89″ x 54 ″	78½″	2½″	4 ″	9½″ & 15 ″	6″
MP 6–75–310			125	600		102″ x 60 ″	94½″	3 ″	5 ″	10½″ & 18 ″	8″

Ratings of sets with compound engines are based on 125 lbs. steam pressure condensing, or 140 lbs. non-condensing.

General Electric Type C. E. Generators and Motors.



(For setting in the usual manner.)



(For mounting on the wall or a post.)

These small generators, ranging in capacity from 1½ to 15 K. W., and motors ranging from 2 to 20 H. P., are especially designed for small belt driven exciters, for small isolated lighting or power plants and for small motor work generally.

The bearings are supported by end shields, which protect the armature and field windings. They are symmetrical, and may be installed either on the floor, ceiling, or wall.

The motors will operate one hour at 25% overload and temporarily under a 40% overload without injurious heating.

Table of Sizes, 125 Volt Generators and 110 Volt Motors.

Classification.						Machine.			Base Frame.				Pulley.	
Compound Wound Generators.				Shunt Wound Motors.										
Poles.	K. W.	Speed.	Amp.	H. P.	Speed.	Length of Shaft.	Height.	Width.	Width.	Length.	Height.	Bolt Holes.	Diameter.	Face.
2	1½	1350	12	2	1060									
2	2¼	2100	18	3	1600	27 5/8	16¼	17	17 3/8	27¼	2 15/16	11/16	5	4
2	2¼	1350	18	3	1060									
2	3¾	2100	30	5	1600	30 5/8	19 11/16	20⅛	17¾	30¾	3¼	11/16	5	4½
2	3¾	1350	30	5	1060									
2	5½	1875	44	7½	1475	32 15/16	21⅛	21 5/8	19 3/8	31 3/4	3 1/4	11/16	5	4½
4	5½	1050	44	7½	795									
4	7½	1625	60	10	1220	38¼	23¾	26	22	38	3 15/16	13/16	7¾	6
4	7½	850	60	10	635									
4	11	1300	88	15	975	41⅛	27⅛	31½	23¼	44	4 5/16	13/16	9¾	7
4	11	850	88	15	665									
4	15	1300	120	20	1000	48½	29 15/16	33	25½	43	5	13/16	10	8½

ELECTRIC LIGHTING.

"**Isolated lighting**" plants and "**central station lighting**" are terms used to designate respectively :

(1). Individual plants where the consumer, utilizing his own power, generates current for his own purposes.

(2). The latter term designates current that the consumer purchases from a company generating the same for sale and distribution to the general public.

Unless cotton mills purchase both lighting and power from a central station (whether steam or water power is immaterial), their lighting is generally of the former class. In short, if a mill cannot afford to buy current for power, it cannot afford to buy it for lighting and generally installs a small electric light plant of its own.

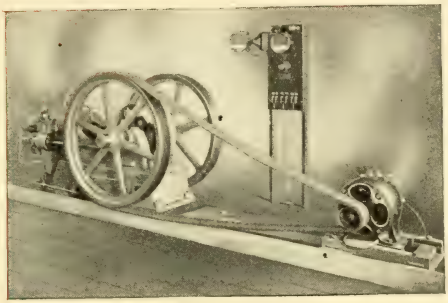
Unless they are of comparatively large units, the apparatus used is direct current ; in large plants, however, the installation of polyphase A. C. apparatus is recommended for reasons that must be obvious from the foregoing pages.

The polyphase generators heretofore described are suitable for lighting as well as for power ; 250 volt machines being generally installed when lighting is the primary object and power is of secondary consideration. Both lights and 220 volt motors can then be run on 220 volt three-wire circuits,—no transformers being required for either If, however, it is desired to operate a few lights in the mill village, or an electric pumping plant, at extreme distances, it will pay to put in a step up transformer for the purpose. (The Washington Mills, at Fries, Va., furnishes an example of this type of installation. See page 829.)

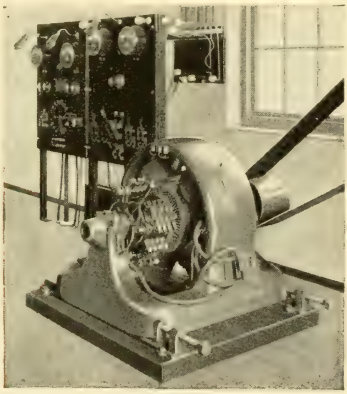
When direct current generators are installed, they are generally of 125 volts, and both lamps and motors are fed from two-wire circuits.

The neatest and best all around type of apparatus unquestionably is composed of direct connected units ; (see pages 660, 662, 872, 873, and 876-880.)

Electric Lighting, Continued.



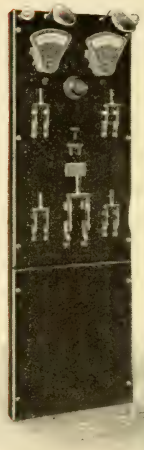
The above cut illustrates a small plant consisting of a General Electric C. E. generator driven by an oil or a gas engine.



This plant shows a G. E. Form H multipolar generator either belted to line shafting or to a separate "electric light engine" of the automatic type; (see pages 659, 661 and 671.) The switchboard shown consists of a generator panel and a feeder panel,—the latter having indicating instruments on it as well as the generator panel, a rather unusual and generally unnecessary arrangement.

Electric Lighting, Continued.

Switchboards for Direct Current Apparatus.



Wherever electric generators are installed, more or less controlling apparatus is necessary, which is most suitably grouped on a switchboard. These switchboards are composed of one or more panels of marble or black enameled slate, according to the purchaser's fancy. A small board for one generator and two to four feeders can advantageously be made of but one panel, consisting of an upper and lower slab. The accompanying illustration shows such a unit and is equipped with the following devices:

One double-pole, single-throw generator switch and fuses.
Two (four, or six) double-pole, single-throw feeder switches and fuses.
One ammeter with illuminating lamp in generator circuit.
One voltmeter with illuminating lamp.
One ground detector switch with lamps.
One double-pole voltmeter switch.
Necessary mounting equipment for rheostat.
Feeder wire support on back of panel.
All necessary framework supporting the structure and connections.

A more elaborate outfit for a larger number of circuits would consist of one generator panel and one feeder panel; a board for two generators might be composed of two generator panels and one or more feeder panels according to the number of circuits required.

There are an unlimited number of such combinations possible, which it is out of the question either to illustrate or describe. The cut on the following page, however, will give a good enough idea of this class of work. It diagrammatically explains the switchboard illustrated above.

Electric Lighting, Continued.

Switchboards for Direct Current Apparatus, Concluded.

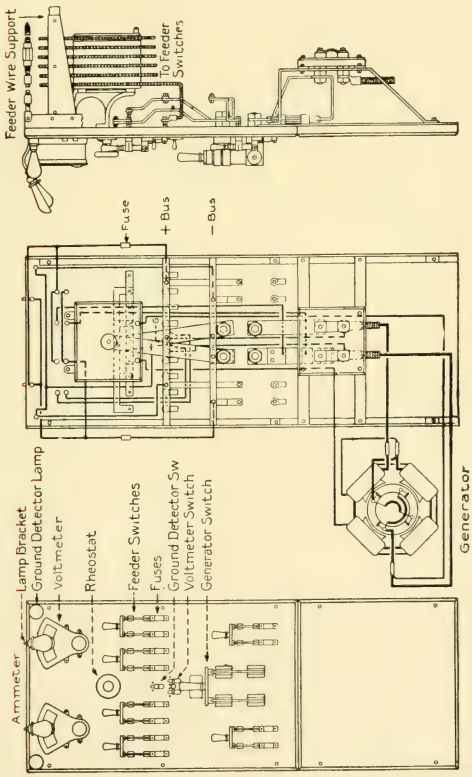


Diagram of a G. E. One Panel Switchboard.

(Fuses for 300 amperes and above are on back of panel; smaller fuses are on front.)

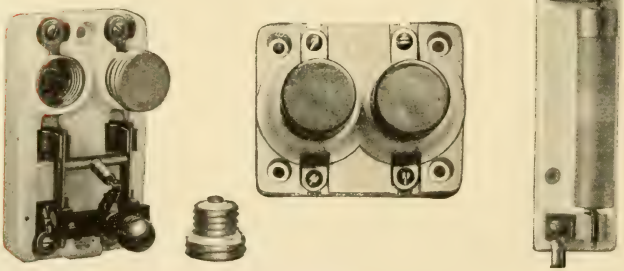
Dimensions: 76″x24″x1½″ up to 600 amperes capacity.
76″x30″x1½″ 800 amperes and above.

Electric Lighting, Continued.

Electrical Supplies.

G. E. Cabinet Panels.

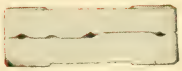
In connection with the equipment of an isolated plant, a most convenient device is found in cabinet panels. These are intended for use at the various centers of distribution about a large building, and besides being extremely convenient they present a very attractive appearance. The panels are of black enameled slate, and all the metal parts are polished copper. The fuses used on these panels are of the convenient Edison plug type, which are commended for their safety and the convenience with which they may be replaced without the use of tools.



Cut-Outs.

Electric Lighting, Continued.

Electrical Supplies, Continued.



Porcelain Cleats.

Porcelain Knobs.

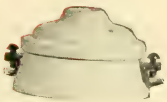
Lamp Sockets for Drop Lights.

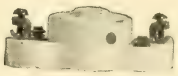
Porcelain Sockets For Dye Works, Etc.

Weather-Proof Sockets.

Porcelain Recep-tacles for Cleat Wiring and Concealed Wiring.

Attaching Plugs.





Rosettes.

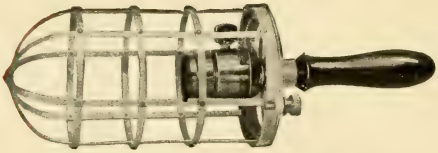
Electric Lighting, Continued.

Electrical Supplies, Concluded.

Socket Bushings.

Cord Adjusters.

Shade Holders.



Lamp Guard and Portable Lamp Holder.

Flush Pocket Switches.

Pendant Push Button Switches.

Snap Switches.

Electric Lighting, Continued.

Arc Lights.

Arc Lamp Hanger Board and Arc Lamps.
(Without Concentric Diffuser.)

The advantages of arc lighting over incandescent for weave rooms are considerable, especially on either colored or fine work ; the whiter light from the arc light seems to make the colored threads in particular stand out plainer than the yellow light from the incandescent lamps.

There are two types of "arc lamps," the open and the enclosed.

The "open arc" type are more fitted for street illumination ; while the light from them in certain directions is very intense, the shadows in other directions are equally dense, and practically preclude their employment in factories.

The "enclosed arc" type have entirely remedied this trouble, and with the additional device of the "concentric diffuser" they furnish an ideal light for a weave room. One such arc light for every 12 to 16 gingham looms that are belted from below will give better light at less cost than one 20 candle power incandescent lamp to each loom. This means that one such light will cover a floor space of from 600 to 800 square feet. Where the looms are belted from above, this should be reduced from 20% to 25%.

The cut shown above illustrates the new G. E. inclosed arc lamp, with concentric diffuser. It will no doubt be alleged that considerable of the light is lost by absorption both of the opal shades and also of the diffuser itself. This is no doubt true ; but, for that matter, it will be recalled that the now almost universal practice of using ribbed glass in the windows is open to practically the same objection. We do not use ribbed glass in the windows of modern cotton mills under the impression that there is no loss of light ; there is

Electric Lighting, Continued.

Arc Lights, Concluded.

(G. E. Enclosed Arc Lamp with concentric diffuser.)

an actual loss of light, but the diffusion is better and shadows are practically eliminated. There is just as distinct and decided a gain in the general illumination of a room lighted with the arc lights and concentric diffusers as there is in the use of ribbed glass in the windows of the same room. The enclosed arc lights with concentric diffusers then may be said to perform the same service for artificial light that ribbed glass in the windows perform for daylight.

Arc Lighting Data.

The carbons on these lamps are 12″ x ½″ upper carbons, and 5½″ x ½″ lower carbons; when the lamps require trimming, the half burned out upper carbons are simply placed below and new upper carbons put in. One trimming will last from 100 to 150 hours, according to circumstances.

A. C. lamps require 6 amperes at 110 volts, or 660 watts; the power factor of an A. C. lamp is rather low, however, and though the actual amount of power consumed is ⅔ K. W., the apparent amount is ¾ K. W.,—and therefore ¾ K. W. is the amount allowed in figuring generator capacity, or 1 mechanical H. P. in engine capacity.

D. C. lamps take only 5 amperes at 110 volts, but still had best be figured also on a basis of one light to ¾ K. W. generator capacity, or one light to 1 mechanical H. P. in engine capacity.

As already stated, one lamp with diffuser will light from 12 to 16 looms driven from below, or 600 to 800 square feet of floor space; these figures should be reduced 20% to 25% when the looms are driven from above.

It will thus be seen that mill lighting will require approximately from .9 to 1.3 watts per square foot for plain white goods, and 1 to 1.5 watts per square foot for colored goods.

Incandescent Lamps.

(With Edison Base.)

The remarkable success of the Edison and Sawyer-Man lamps has stimulated competition by a great many smaller makers, until the market is flooded with inferior goods. In fact, it is probably not overdrawing it to state that 90% of the lamps other than the two mentioned above are not worth one-half even the low prices charged for them.

Very few people are in a position to judge of the relative value of an incandescent lamp.

The value of lamps is frequently expressed in terms of candle power hours they will give before falling below a specified limit at which they should be discarded. There is poor economy in using lamps after they have fallen below this limit. As a general statement it may be said that an old 16 candle power lamp will often be found to require as much current after it has fallen to 10 candle power, as it does to burn a new lamp at 16 candle power.

It is a common trick of the trade for unscrupulous dealers to represent their lamps as burning longer than 600 lamp hours, which has been adopted as the standard for the best lamps. They do not explain that after probably one-third to two-thirds of that time their lamps will already have fallen off in efficiency probably below that of the standard, which fact would not be readily detected by the average consumer, because they would still burn.

As a general statement, a high efficiency lamp means a short-lived lamp, and a low efficiency lamp means a long-lived lamp, as shown by the following table:

Watts per Candle.	Life.	Watts per Candle.	Life.
	Per cent.		Per cent.
3.0	46	3.6	115
3.1	54	3.7	132
3 2	64	3.8	151
3 3	74	3.9	172
3.4	87	4.0	195
3 5	100		

Electric Lighting, Continued.

Incandescent Lamps, Concluded.

The service of even good lamps is often seriously impaired by bad regulation, as will be shown in the following table of voltages above and below normal. It will be noticed that when the volts are increased only 10%, the candle power is increased 69%. The power or watts required per candle are reduced 38% and the life of the lamp is reduced 80%. Equally unsatisfactory is the performance of lamps at voltages 10% under normal. For instance, the candle power is decreased 45%, the watts increased 47½%, though the life of the lamp is increased 610%.

Volts.	Candle Power.	Watts Per Candle.	Life.
Per cent.	Per cent.	Per Cent.	Per cent.
110	169	72	20
109	161	74	22
108	153	76.5	26
107	145	79	30
106	138	81 5	35
105	131	84	41
104	124	87	49
103	118	90	59
102	111	93	69
101	106	96.5	83
100	100	100	100
99	95	103	115
98	90	106	132
97	85	109.5	155
96	80	113.5	188
95	75	118.5	232
94	71	123 5	290
93	67	128	363
92	63	134	460
91	59	140.5	560
90	55	147.5	710

Choice and Selection of Lamps.

The adaptability of the incandescent lamp to picker and card rooms lies in the fact that a relatively small amount of light is required; for spinning, twisting, spooling, warping, and similar purposes, where a great deal of light is required, it permits the concentration of that light around the machines: in weave rooms, however, which require not only a good strong well-diffused light but also, particularly for colored work, a white light seems desirable, the arc lamps seems to be better adapted.

Plant Installation.

Generators.—The direct current machines usually installed in cotton mills in connection with their own lighting plants are seldom located in a separate dynamo room—the engine room under the eye of the engineer is probably the best practice.

They must, of course, be located in a dry place, and if set on the floor they must be properly insulated, and kept clean and dry. It is better practice to set them on brick foundations, if possible. Each machine should be provided with a water proof cover.

It is also to be protected from excessive current by a suitable circuit breaker, or fuses.

Switchboards.—These must be made of non-combustible materials, or hard wood in skeleton form, filled to prevent absorption of moisture. Slate or marble is recommended. They must be kept free from moisture, and must be accessible from all sides when the connections are on the back. The bus bars must be made of bare metal, rigidly fastened in place. Knife switches should be so placed that gravity will tend to open rather than to close the switch.

Conductors.—From generators to switchboards, rheostats, or other instruments or extending to outside or inside lines, the conductors must be in plain sight and readily accessible. They must have an improved insulating covering.

Inside Wiring.

The style of work ordinarily installed in a cotton mill is termed "open cleat" work, the lamps being suspended by flexible drop cord from porcelain ceiling rosettes. The circuits are either two or three wire circuits, according to whether there are one or two generators. Both rubber covered and triple braided weather proof wire are acceptable when installed according to insurance requirements, with complete porcelain trimmings, such as cut outs, branch blocks, rosettes, cleats, insulating knobs, tubing, etc.

There are three ways of running wires in circuits extending longitudinally in the buildings :

(1.) The heavy floor planking forming the ceiling overhead can be put in three-quarters to one inch less in thickness where the circuits are to be run, thereby providing channels above the heavy timbers. The objection to this method, however, is the fact that the channels over the timbers become little better than catch-pits for lint and dirt.

(2.) The wires can be run along the ceiling of the bays between the timbers, and then down under the timbers, suitably protected therefrom by porcelain cleats or insulators. This does not make a neat job, however, and gives an unnecessary amount of wire and trimmings to be maintained and kept up.

Electric Lighting, Continued.

Inside Wiring, Continued.

(3) Holes can be bored through the heavy timbers overhead, and bushed with porcelain tubes through which the wires may be run from one end of the mill to the other, if desired. This makes a neat and lasting job when the mains are properly anchored at the end of each circuit. It is probably the best method of running mains.

Wires.—These must not be smaller than No. 14 B. & S. gauge. Tie wires must have an insulation equal to that of the conductors they confine. Wires must be so spliced or joined as to be both mechanically and electrically secure without the solder. They must then be soldered to insure the preservation, and the joints properly taped to give an insulation equal to that on the conductors. Stranded wires must be soldered before being fastened under clamps or binding screws, and when they have a conductivity greater than No. 10 B. & S. gauge copper wires they must be soldered into lugs. Wires should be kept separate from contact with walls, floors, timbers, or partitions through which they must pass, by non-combustible non-absorbing insulating tubes, such as glass or porcelain. The bushings must be long enough to bush the entire length of the hole in one continuous piece, or else the holes should first be bushed by a continuous water proof tube, such as a piece of pipe; the insulating tubes can then be bushed in at each end so as to keep the wire entirely out of contact with the conducting pipe. Particular care must be observed to keep wires free from contact with gas, water, or other metallic piping, or any other conductors or conducting material which they may cross. Wires must also be so placed in wet places that an air space will be left between conductors and pipes in crossing, and they must be run in such a way that they can not accidentally come into contact with the pipes. Wires should be run over rather than under pipes upon which moisture is likely to gather.

Flexible cord pendants must be protected by insulated bushings where the cord enters the socket: they must also be so suspended that the entire weight of the socket and lamp will be borne by knots under the bushing in the socket and above the point where the cord comes through the rosette on the ceiling, so that the strain will not be on the joints and the binding screws. These flexible cords are made of stranded copper conductors, each strand not larger than No. 26 nor smaller than No. 30 B. & S. gauge; the total of each stranded conductor having a carrying capacity not less than No. 18 B. & S. wire.

Terms Used in Electric Lighting.

The Ampere is the unit of current.

The Volt is the unit of pressure.

The Ohm is the unit of resistance.

The Watt is the unit of electrical energy and is the product of one ampere and one volt.

One Electrical Horse-power is equal to 746 watts.

One Kilowatt is equal to 1000 watts.

Examples:

Find watts generated by a dynamo having a capacity of 50 amperes at 125 volts:

$$125 \times 50 = 6250 \text{ watts} = 6.25 \text{ K. W.}$$

Find current required for 50-16 C. P. 3.5 watt lamps at 11 volts:

$$50 \times 16 \times 3.5 = \frac{2800 \text{ watts}}{110 \text{ volts}} = 25.45 \text{ amperes.}$$

Find electrical horse-power required by 100-16 C. P. 50 watt lamps:

$$\frac{100 \times 50}{746} = 6.7 \text{ electrical horse-power.}$$

(See page 865.)

The *drop* in any conductor is the loss of voltage due to the resistance overcome in forcing current through it. In all cases except where alternating currents are to be used, the "drop" is equal to the current it carries in amperes multiplied by its resistance in ohms. The drop may be expressed either in volts or in percentages of voltage delivered; reckoning in percentages is usually preferred, because then the drop shows the proportion of loss in the line.

Lamp feet is a convenient term used to facilitate laying out wiring and calculating the drop; it simply means the number of lamps that are connected to a feeder or main, multiplied by the distance in feet from the point of supply to the center of distribution.

Ampere feet is a term the significance of which is apparent from the above explanation of "lamp feet."

The term *feeder* is given to the wires that lead from the switchboard or main block to the branch blocks for the distribution.

The *mains* or *circuits* are the branches taken off from the feeder at the branch blocks.

A *tap* is a branch taken off from a circuit for one light, one motor or any other unit.

The *center of distribution* is a term applied indiscriminately to an entire plant, a single section, a feeder, its mains, or a main or circuit alone. The term "center of distribution" is therefore self-explanatory. When one feeder supplies several mains or circuits, the drop in the feeder and in each circuit must be figured separately; the drop in the

Electric Lighting, Continued.

feeder added to the drop in the circuit is the total drop to any center of distribution. As nearly as possible the drop should be the same in all branches, sub-feeders and mains and to each center of distribution.

Circular Mils.—A mil is $\frac{1}{1000}$ inch, and is the unit of measurement in wiring. A circular mil is the sectional area of a wire one mil in diameter. The area of a wire in circular mils is, of course, proportional to the square of the diameter; for example, a wire whose diameter is 460 mils is 460x460= 211,600 circular mils.

In General.

Standard incandescent lamps are made in three efficiencies known as 3.1; 3.5 and 4 watts per candle.

Thus a 16 candle-power 3.1 watt lamp consumes 49.6 watts or practically 50 watts. A 16 C. P. 3.5 watt lamp consumes 56 watts. A 16 C. P. 4 watt lamp consumes 64 watts.

For ordinary isolated plants the 3.5 watt lamp is recommended.

A kilowatt equals 1000 watts, so a 25 K. W. dynamo would have a capacity of

$$\frac{25000}{56}=446$$—16 C. P. lamps without allowing for any losses in the lines. If 3.1 watt lamps are used a greater number can be connected.

Example:—Find dynamo capacity required to supply 325-16 C. P. 3.5 watt lamps allowing 10 per cent. losses:

325x16x3.5=18200 watts=90% total watts.

$$\frac{18200}{.90}=20220 \text{ watts}=20.22 \text{ K. W.}$$

In mills of various kinds it is customary to allow 5% loss in feeders from the dynamo to the center of electrical distribution, and 2% loss in the mains from which the lamps are served.

The "thumb rule" for 16 C. P. lamps is to allow 12 to the H. P., 18 to the K. W., and ½ ampere each to the lamp.

Simple Rules for Finding Correct Size of Wire for Two-Wire Service.

The square of the diameter of any given wire expressed in mils (1 mil=.001") gives the circular mils.

M=Circular Mils.
C=Current Amperes.
D=Average Distance Current is transmitted one way.
P=Per Cent. Loss allowed.
21=Constant.

To ascertain size of wire:

$$M=\frac{CxDx21}{P}$$

Example:

Find size of wire necessary to transmit current for 200-16 C. P. 3.5 watt lamps at 120 volts dynamo pressure a distance of 600 feet, allowing 5 per cent. loss.

5 per cent. of 120 volts=6 volts which will give 114 volts at center of distribution. Allowing 2 volts more for losses in the mains and services we would use 112 volt incandescent lamps.

$$So\frac{200 \times 16 \times 3.5}{112}=100 \text{ amperes.}$$

$$M=\frac{100 \times 600 \times 21}{6}=210000.=\text{No. 0000 wire.}$$

Table Showing Carrying Capacity of Wires.

Size of Wire. 98% Conductivity.		Carrying Capacity in Amperes.	
B. & S. G.	Circular Mils.	Rubber-Cov'd Wires.	Weather-proof Wires.
18	1,624	3	5
16	2,583	6	8
14	4,107	12	16
12	6,530	17	23
10	10,380	24	32
8	16,510	33	46
6	26,250	46	65
5	33,100	54	77
4	41,740	65	92
3	52,630	76	110
2	66,370	90	131
1	83,690	107	156
0	105,500	127	185
00	133,100	150	220
000	167,800	177	262
0000	211,600	210	312
	200,000	200	300
	300,000	270	400
	400,000	330	500
	500,000	390	590
	600,000	450	680
	700,000	500	760
	800,000	550	840
	900,000	600	920
	1,000,000	650	1,000
	1,100,000	690	1,080
	1,200,000	730	1,150
	1,300,000	770	1,220
	1,400,000	810	1,290
	1,500,000	850	1,360
	1,600,000	890	1,430
	1,700,000	930	1,490
	1,800,000	970	1,550
	1,900,000	1,010	1,610
	2,000,000	1,050	1,670

The lower limit is specified for rubber covered wires to prevent gradual deterioration of the high insulation by the heat of the wires, but not from fear of igniting the insulation.

While the carrying capacity of No. 16 and No. 18 wire is given above, still, as already pointed out, no smaller than No. 14 is allowed by insurance regulations without special permission.

(See page 710, where it will be noted that these same carrying capacities are also designated respectively for open cleat work and concealed work, and for 32 degrees C. rise and for 16 degrees C. rise of temperature.)

The question of drop is not taken into consideration in the above table.

PRIVATE TELEPHONE SYSTEMS.

Not only are telephones a necessity in connection with the pole line of a plant for the electric transmission of power (see pages 718 and 719); but they are also a great convenience for intercommunication between the different departments of any cotton mill.

There are quite a number of fairly efficient intercommunicating telephone sets on the market, but it is not out of place to suggest that the cheapest instrument is probably not the best. Good sets can be bought at moderate prices, with push buttons on each instrument for as many as a dozen or even two dozen intercommunicating stations. For ordinary use the wall type of instrument is most suitable; but for desk use the Ericsson receiver and transmitter combined in one piece will be found most convenient. This is a Swedish invention, but can be obtained from any electrical supply house.

Notes on Line Construction.—The most satisfactory results are given by metallic circuits, and though for short lines iron wire will answer, No. 12 hard drawn copper wire is recommended. These wires should be transposed at least every two miles when on separate poles; but when strung on poles used for power transmission, had best be transposed every fourth pole. The ordinary method of transposing requires a separate transposition glass, so that one wire leads into the top of the glass and the other out from the bottom; making both a substantial construction and the crossing over feasible with but one cutting of the wire.

The poles should be set about 35 poles to the mile, or 150 feet apart, set about 4 feet in the ground in straight lines and 5 feet in rounding curves. The poles should be cypress or juniper, 20 to 30 feet high, and 6 to 8 inches in diameter at top.

The tops of the poles had best be cone-shaped, and painted. The gain on poles should be with two gains 20 to 22 inches apart. The arms should be bolted on to the poles 8 to 12 inches apart from the top with a ½-inch through carriage bolt, with nut and washer. All guys should be anchored. For ordinary mill purposes a six-pin cross arm had best be put up, even if only two wires are needed in the beginning. This small provision for the future costs little or nothing, and is often found convenient. Brace the cross arms with 24 to 26 inch braces, made fast to the cross arms with through carriage bolts on their upper ends, and lag screw with 4"x½" lag screws to the poles on their lower ends. The standard size pins are 1¼ inches, each of which should be nailed into the cross arms with a six-penny wire nail.

APPENDIX
and
Table of Contents.

STEAM TURBINES.

(Turbo-Generation.)

At the outset it is well to state that in this article only steam turbines for direct connection to electric generators will be considered, their usefulness in mill work, at least for the present, being confined to their operation in connection with electric power and lighting.

In the foregoing pages the electrical end of the question has already been quite fully enough considered for the purposes of this book so far in as general information is concerned; and as for anything specific, details are unnecessary other than the number of poles, number of revolutions, number of cycles, number of phases, and voltages—all of which appear under their proper headings in the tables of standard sizes.

Principles of Operation.

In the first place, it is well to discriminate between the principles upon which the ordinary type of reciprocating engine operates and those applying to steam turbines.

In a reciprocating engine work is done directly by the expansive force of the steam exerted on the piston; whereas, in a steam turbine the expansive force only imparts motion to the steam itself, and this motion is given up to the revolving part by impacts of the moving steam upon it.

*"The idea of the steam turbine is quite simple, and is similar to that of the water turbine or impulse wheel. The practical difficulty which has heretofore prevented the development of good steam turbines, lies in the very high velocity which steam can impart to itself in expansion, and the difficulty in efficiently transferring this motion to wheels at speeds practicable for construction or practical use. Steam expanding from 150 pounds gauge pressure per square inch into the atmosphere, is capable of imparting to itself a speed of 2,950 feet per second, and if it is expanded from 150 pounds gauge pressure into a 2-inch vacuum it can attain a velocity of 4,010 feet per second. The spouting velocity of water discharged from a nozzle with 100 feet head, is 80 feet per second. These figures illustrate the very radical difference of condition between water turbines and steam turbines. In both water and steam turbines the theoretical condition of maximum economy exists when the jet of fluid moves with a velocity equal to about twice that of the vane against which it acts. In water wheels this relation is easily established under all conditions, while with steam the total power produces a velocity so high that the materials available for

*Note.—See "The Curtis Steam Turbine," by W. L. R. Emmet.

Steam Turbines, Continued.

simple wheels and vanes are not capable of sustaining a proper speed relation to it under practicable conditions."

*"An ideal elementary turbine may be said to consist of a steam nozzle directing a tangential jet of fluid upon a bucket wheel of the Pelton type. This type of bucket is selected because it may be capable of giving a complete reversal to the jet, so that the spent fluid may issue from the buckets without any velocity. Even this type may not be quite ideal, because of the distance which must necessarily exist between the outlet of the nozzle and the receiving wedge of the buckets, the effect of which will be to cause friction between the jet and the surrounding medium, causing eddies, and perhaps entraining some of this surrounding medium."

"Steam expands approximately adiabatically in the nozzle, and on its arrival at the exit should be thoroughly expanded to the exhaust pressure, so that its heat energy may be entirely transformed into kinetic energy, and its velocity be the greatest attainable on striking the buckets. For conditions of maximum efficiency, the same relation between velocities of jet and vane applies to the steam impulse wheel, as to its hydraulic analogue; viz., bucket speed equals one-half of jet speed."

"The difficulty of such a design as this is obviously due to the fact that the velocity of steam expanding between even moderate differences of pressure, is so high as to render the most efficient velocity of the bucket difficult to provide for because of the limitations of strength of materials. Thus, for terminal pressure of 165 pounds and 1 pound respectively, the bucket speed should be 2,025 feet per second. In practice, the maximum attained is 1,378 feet per second in a 300 horse-power De Laval turbine, which is 32 per cent. below speed. In a 50 horse-power turbine, the bucket velocity is 58 per cent. below normal, but even at this speed, the radial stresses amount to 23,000 pounds per square inch."

"The so-called phenomenon of maximum flow of steam through an orifice is now generally understood. It has been generally stated that the velocity of steam flowing through an orifice will not exceed about 1,500 feet per second, no matter what the differences of pressure may be. This condition has been said to be reached when the exhaust pressure bears a certain ratio to the initial pressure. This ratio has been variously given from 52 per cent. to 58 per cent."

"Experiments made at East Pittsburg, however, seem to show that the above figures vary with the initial pressure. The velocity becomes higher and the above ratio lower with the lower initial presure. Therefore, in the above-mentioned

Note—See "Some Theoretical and Practical Considerations in Steam Turbine Work," by F. Hodgkinson.

Steam Turbines, Continued.

elementary turbine, if the initial pressure is 150 pounds per square inch, and the exhaust pressure is greater than 85 pounds (57 per cent. of the initial pressure), all that is needed in the shape of a nozzle is a well-rounded orifice. If the exhaust pressure is less than 85 pounds, a divergent nozzle, as used by Gustav De Laval, is necessary. Without this divergence, the steam will expand outside of the nozzle where it is uncontrolled by its walls, and consequently much of the expansion will take place laterally, which will not further accelerate the jet."

"A further reason for the divergence is apparent from the fact that the work done by the expanding steam varies nearly in direct proportion to the number of expansions, and also varies directly as the square of the velocity. The volume of the steam, therefore, increases much more rapidly than the velocity, and room must be provided for its proper expansion in the nozzle."

"It is probable that the state of steam issuing from a good-sized nozzle does not deviate much from the ideal. The only losses will be due to the friction and conduction of heat along the walls. The larger the nozzle, the less will be the ratio of perimeter to cross section, and consequently the less these losses will become. In the ideal turbine above mentioned, if the form and velocity of the buckets were such that they might wholly absorb the velocity of the jet without friction, the state of the steam on leaving the buckets would be the same as when it left the nozzle, and we would have a turbine approximating an ideal engine, except for the frictional losses of the nozzle."

"In practice, the kinetic energy cannot be wholly absorbed, the buckets cannot generally be arranged to satisfactorily make a complete reversal without attendant disadvantages; hence the steam issues from the bucket with residual velocity. Where the jet is arranged to impinge upon the bucket wheel tangentially or at the sides, a departure from the ideal occurs. In the De Laval type, complete reversal cannot be obtained, as the spent steam must clear the buckets; in the Pelton type, the angular position of the bucket with reference to the jet is continually changing, resulting in distortion of the jet from its ideal path. There is also in some forms a spill from the buckets, and always frictional losses and eddies, which have the effect of lowering the velocity and heating up the steam similar to, but to a less extent than, the effect in a throttling calorimeter."

"With high steam velocities, the skin friction of the fluid passing over surfaces such as buckets amounts to a considerable loss, though the exact amount of such losses is unknown."

Steam Turbines, Continued.

"In the type of turbine above described, the velocity of the steam is approximately twice that of a rifle bullet."

"Dr. Stodola, in his excellent work, 'Die Damp Turbine,' quotes a test by Lewici upon the friction of a 30 horse-power De Laval disk in air and vacuum. The turbine was driven by a calibrated motor, and in order to bring it up to speed, the following power was required:

		Resistance.	
		Atmosphere.	19.6″ Vacuum.
Dry saturated steam....	3.3 H. P.=	11 per cent.	5 per cent.
Superheat 300 degrees C.		6 25 per cent.	2 per cent.

"In view of these facts, it would seem desirable to avoid high steam velocities as much as possible, because of the resulting frictional losses. Another reason is the erosive action of the steam with high velocities. This is quite serious when the steam is initially wet, due to foaming boilers. In this case matters are generally made worse by the moisture generally carrying with it various kinds of solid impurities."

"In this connection, the author lately had some hard drawn Delta metal blades exposed to two steam jets, the one issued from a diverging nozzle with 150 pounds boiler pressure behind it, and the other from a rounded orifice with 1 pound pressure. The size of the outlet of the two nozzles is the same in each case, and the respective velocities were approximately 2,900 and 600 feet per second."

"The blades were kept continuously exposed to the jets for one hundred and twenty-eight hours."

"A considerable amount of erosion was observed on the blades subjected to the higher velocity."

"A rather curious feature, too, is that the erosion was maximum at the center and the extreme edges of the jet."

"No attempt was made to observe the quality of the steam; the nozzles were merely connected to a steam pipe in the works."

Types of Turbines.

"The ideal turbine that has been above referred to is essentially a refined form of that built by Branca, in 1629. The present De Laval turbine may be said to be of a like type, in so far that its elements consist of one single bucket wheel and one set of expanding nozzles."

The Stumpf.—A more recently developed turbine, Stumpf, likewise utilizes these distinguishing elements of the simple impulse turbine, with, however, a slight departure from the De Laval arrangement in the use of tangential nozzles with buckets of the Pelton form milled in the periphery

Steam Turbines, Continued.

of the wheel. These are slightly pitched from the shaft in order to provide metal for succeeding buckets. A characteristic of this form of turbine is the large wheel diameter employed, and it is in this direction that low shaft speeds are secured. For example, a 500 horse-power turbine with two disks 5 feet in diameter has been constructed and run at a speed of 3,000 revolutions per minute with a rigid shaft. In later forms of the Stumpf turbine, it has been sought to utilize a residual velocity of the steam leaving the buckets by redirecting it around a circular guide, so as to impinge again upon another set of buckets, milled in the periphery of the wheel, alongside the other row. The steam jet, after leaving the nozzle, is, therefore, reversed 180 degrees twice before finally leaving the wheel. It is evident, however, that this arrangement is subject to the same disadvantage as regards fluid friction, as the simple impact arrangement."

Compound Systems.—On account of the difficulties of construction, and losses attendant upon the use of high steam velocities, various methods of compounding have been proposed, the objective point of the compounding arrangement being a subdivision of total velocity among several stages, so that the working velocities in any one stage might be reduced to a more practicable degree. The effect of compounding does not, however, reduce the stage velocities as promptly as might be at first thought, for the reason that the velocity varies as the square root of the energy of the steam. Thus, if the simple impact turbine were constructed with two stages instead of one, the stage velocity would be reduced from 4,012 feet per second to 2,835 feet per second, assuming a range of pressure from 165 pounds to 1 pound absolute. If it were constructed in four stages, the velocity would become 2,050 feet per second, under the supposition that the entire velocity of the jet were abstracted in each stage. In order, therefore, to reduce the steam velocities to 500 feet per second, about 64 stages would be required in the turbine."

The Curtis.—The nearest approach to this method of compounding the simple impact element is carried out in the Curtis turbine, in which two or more stages are employed to carry out the total range of expansion from boiler to condenser. Each stage comprises a set of expanding nozzles and a wheel carrying more than one row of buckets. The peripheral speed of the wheel is kept within convenient limits, so that if only one row of buckets were employed, the steam would issue from it with much residual velocity."

"In order to abstract this as far as possible, a set of guides is interposed which redirects the steam leaving the first row of moving blades, into a second set. The velocity of the jet

Steam Turbines, Continued.

is thus reduced by each reversal in the moving blades, and this process is carried out as many times as may be necessary to absorb the initial velocity of the jet. Thus the steam in each stage is alternately accelerated in the nozzle and retarded in the blades. Low shaft velocities are secured by this arrangement, but this is largely due, however, to the use of large diameters of wheel, and to the fact that, generally, a very small arc of all but the last wheel is being acted upon by the nozzle at one time. This construction makes desirable a fine axial clearance."

The Zoelly.—The idea of compounding has been applied in a slightly different manner in the Zoelly turbine, one section of the turbine—the high-pressure end—consisting of several tangential impulse elements arranged in separate compartments. Each is fitted with a number of nozzles in which part of the expansion is carried out, and the velocity immediately abstracted in the buckets. In the later stages, however, a different construction is employed by reason of the increased volume of steam. The principal features of the Zoelly turbine lie, however, in the construction of the disk wheel to accommodate extraordinarily high peripheral speeds. The buckets consist of metal strips about one-half the radius of the wheel length. They are secured to a two-piece hub by projections, and a cross section of approximately uniform strength is obtained by milling the bucket curves deeper from hub to rim. Thus, the weight is largely decreased, as are also the internal stresses to be provided for. Zoelly found by experiments that his buckets might be spaced much farther apart than customary in the De Laval turbine, without serious loss in efficiency, which justifies his construction. The peripheries of the bucket wheels are surrounded by stationary metal shrouds to prevent radial escape of the steam. The sides of the buckets are further enclosed in sheet-steel housings to reduce the windings which would occur with exposed buckets of such length. Complete reversal of the steam jet is impossible, and the action is similar to that of the familiar Pelton wheel."

The Rateau.—Professor Rateau, in his later form of turbine, has discarded the simple impact element and employed the subdivided element to a still greater extent than any hereinbefore described. Annular nozzles are provided in each division wall between stages. The stages being numerous, the pressure drops are small, such that the nozzles require no divergence. The increasing nozzle area is secured through increasing the arc, or percentage of total circumference, rather than the nozzle width, as in the Zoelly form. Thus in the later stages, a complete annular jet results, and the

Steam Turbines, Continued.

entire periphery of the wheel is made use of. This seems a decided step in the direction of reducing fluid velocities, but even this form is subject to frictional losses, due to large disk areas operating at high speeds in dense media."

"A still further method of securing the advantages of compounding is represented in the construction of the Parsons turbine, which, however, antedates, both in conception and introduction, other forms of modern steam turbines."

Parsons.– In the types previously described, the original impact element has been made use of in simple or compounded form, the pressure fall being secured by nozzles and the velocity abstracted by vanes. Thus each bucket wheel presumably rotates in an atmosphere of uniform pressure at all points. Mr. Parsons, however, early conceived the idea of so designing and locating the turbine vanes that they should perform the functions of bucket and nozzle as well, at the same time confining the steam to the periphery of the wheel in order to avoid superficial friction in large disk areas. The actual construction of this type of turbine will be described later.

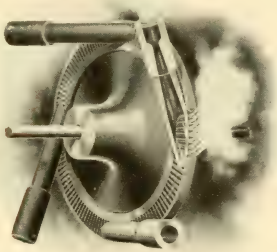
Briefly stated the steam volume progressively increases from inlet to exhaust in an annular space between the stationary and the rotating parts.

"The entire expansion, which is approximately adiabatic, is carried out within this annular compartment which essentially corresponds to a simple steam nozzle. There is this difference, however, that whereas in a nozzle the heat energy of the entering steam is expended upon itself in producing high velocities of efflux; in the Parsons turbine the total velocity due to expansion, is subdivided into a number of steps, in each of which it is reduced through the dynamic relation of jet and vane, so that a comparatively low velocity is maintained from inlet to exhaust; this generally varying from 150 feet per second as a minimum at the high-pressure end to about 600 feet per second as a maximum at the low-pressure end. The action of the steam in this turbine differs from other types also in this respect, that the steam expands in the ring of moving blades, so that a reactive effect is produced in addition to the impulse from the impact of the steam jets. Technically, this turbine is of multiple expansion, parallel flow type."

Of the turbines above mentioned, there are only three that have become fairly well known and in more or less general use in the United States; therefore, further description will be confined entirely to those three, which may be stated in order of priority of invention and introduction as follows:

THE DE LAVAL TURBINE.

In the De Laval turbine, the total power of the steam is devoted to the production of velocity in an expanding nozzle which produces velocity very efficiently. The jet so produced is delivered against a set of vanes on a single wheel which, by an ingenious construction and method of suspension is adapted to operation at a very high peripheral velocity. The very high rotative speed which this construction entails, is made available for dynamo driving by very perfectly made spiral-cut gears which effect a ten-to-one speed reduction.



The above cut makes clear the construction of the De Laval turbine. The power of the turbine depends on the number of nozzles in action, and these nozzles can be opened or closed by a hand wheel on each. Regulation of speed is accomplished by a throttling valve, operated by a centrifugal governor. The usefulness of the De Laval turbine is limited because its design does not seem to be conveniently applicable to large sizes. It therefore is not likely to become useful in cotton mill work, except possibly for driving electric lighting units. For purposes of comparison, and as a matter of general information, I herewith append a table of results of a series of tests made on a standard 300 H. P. De Laval steam turbine. The turbine shaft was geared into two other shafts instead of one, which is the usual practice; and on each of the latter shafts was coupled a direct current electric generator, both revolving in the same direction and operating in series.

De Laval Steam Turbines, Continued.

Tests with Superheated Steam, May 22, 1902.

(Average.)

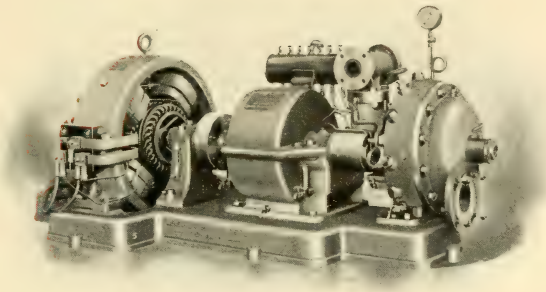
Number of Nozzles Open.	Steam Used per Hour, Lbs.	Pressure above Governor Valve, Lbs.	Pressure below Governor Valve, Lbs.	Vacuum, Inches.	Superheat above Governor Valve, Degrees Fahr.	Revs. per Minute of Generators.	Brake Horse Power.	Steam used per Brake Horse Power per hour, Lbs.
8	4906	207.0	198.5	27.2	84	750	352.0	13.94
7	4282	207.4	197.0	27.4	64	756	298.4	14.35
5	3033	200.7	196.6	27.5	10	743	196.5	15.44

Tests with Saturated Steam, May 22, 1902.

(Average.)

Number of Nozzles Open.	Feed Water Weighed per Hour, Lbs.	Condensation from Separator, Lbs.	Moisture in Steam at Throttle by Calorimeter, Per Cent.	Dry Steam Entering Turbine. Lbs.	Pressure above Governor Valve, Lbs.	Pressure below Governor Valve, Lbs.	Vacuum, Inches.	Revs. per Minute of Generators.	Brake Horse Power.	Dry Steam used per Brake Horse Power per hour, Lbs.
8	5233	70	2.15	5052	206.4	196.9	26.6	747	333.0	15.17
7	4587	60	2.15	4430	207.3	196.5	26.8	746	284.8	15.56
5	3351	51	2.15	3229	207.6	195.8	27.35	751	195.2	16.54
3	2026	33	2.15	1950	201.5	197.9	28.1	751	118.9	16.40

De Laval Steam Turbines, Concluded.



(The above cut illustrates the single type of machine as contrasted to the double type described on the bottom of page 907. In this single type, as will be noticed in the above cut, there is but one generator directly coupled to a single shaft geared to the turbine shaft.)

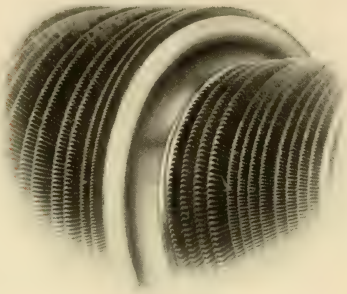
The following table of the standard sizes in which this type of machine is built, may be found interesting:

De Laval Steam Turbine Sets Including D. C. Generators.

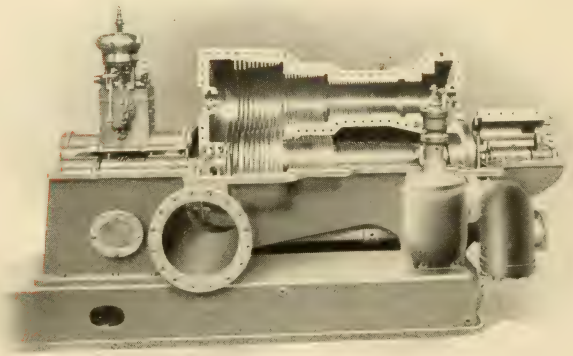
(Condensing or Non-Condensing.)

Brake H. P.	K. W.	R. P. M.	Length.	Width.	Diam. Steam Pipe.	Diam. Exhaust Pipe.
1½	1	5,000	2′ 6″	0′ 11″	½	1
3	2	3,000	3′ 8″	1′ 4½″	¾	1½
5	3.3	3,000	4′ 1″	1′ 10″	1¼	2
7	4.6	3,000	4′ 2″	1′ 10″	1¼	2
10	6.6	2,400	5′ 0″	2′ 1″	1½	3
15	10	2,400	5′ 3″	2′ 2″	1½	3
20	13.2	2,000	6′ 3″	2′ 7″	2	4
30	20	2,000	6′ 4″	2′ 10″	2	4
55	35	1,500	8′ 1″	3′ 3″	2½	5
75	50	1,500	8′ 7″	3′ 10″	3½	6
110	75	1,200	9′ 9″	4′ 7″	4	8
150	100	1,200	10′ 10″	4′ 8″	4	8
225	150	900	12′ 11″	5′ 11″	5	10
300	200	900	15′ 0″	6′ 3″	5	12

WESTINGHOUSE-PARSONS STEAM TURBINE.

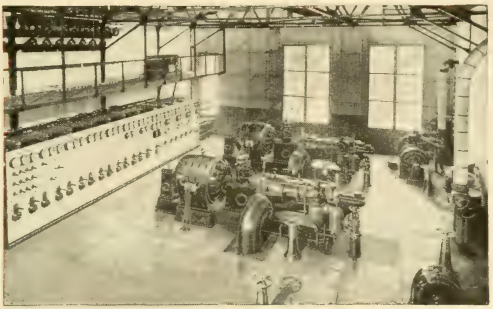


(Enlarged view of a small part of the rotor, showing two of its diameters with the blades in position.)



(The above cut, showing the upper casing turned back, gives a very good general idea of the internal appearance of these machines, the generator not being shown.)

Westinghouse-Parsons Turbines, Continued.



(The above cut illustrates a very neat and attractive installation of Westinghouse-Parsons Steam Turbines, with switchboard, etc.)

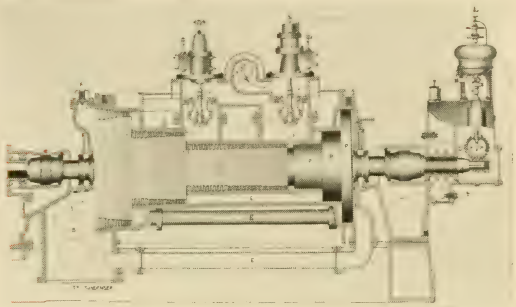
In 1895, the Westinghouse Machine Company acquired the right to manufacture the Parsons turbine in the United States and Canada. They went into the matter most thoroughly, taking their time about it, so that it was 1898-9 when the Westinghouse-Parsons machines were placed upon the market, the first installation being three 400 K. W. units in the works of the Westinghouse Air Brake Company, near Pittsburg. The fourth unit was added later, and in 1900 distributed steam power was entirely displaced at their works. The years 1902-3 have marked the introduction of the Westinghouse-Parsons turbine machinery in all forms of power work on a large scale.

Up to the present time, there have been a quarter of a million horse power in steam turbines built under the Parsons patents abroad, with orders on hand for twice as much more, including the marine type. In this country, the Westinghouse Machine Company have taken orders for over 200,000 horse power of Westinghouse-Parsons machines, nearly half of which are already in operation.

In the South, the first unit was sold in the spring of 1903 to the Consolidated Railways, Light & Power Company, of Wilmington, N. C. After continuous service of a year and a half, in January of this year, 1905, they duplicated the order for another unit of the same size.

So much, therefore, for the general state of the art of turbine building, so far as the Parsons type is concerned. It is impossible to predict too bright a future for it, with the possible exception of the further development and improvement of the internal combustion type of engine, ordinarily

Westinghouse-Parsons Turbines, Continued.



(The above cut shows a general longitudinal section through a Westinghouse-Parsons Steam Turbine.)

included under the general head of gas engines,—which will be considered in a subsequent chapter.

In the smaller machines of this type, the cylinder barrel and both journals are cast in one piece. In large machines, however, the barrel is cast in two sections, united by links. The outboard section carries the journal and worm casing and the inboard section the journal and exhaust opening, which extends through the bed plate.

The steam enters at the governor valve and arrives at the chamber "A" and passes out to the left through the turbine blades, eventually arriving at the exhaust chamber "B." The blades are as shown on page 910, the steam passing first a set of stationary blades and impinging on the moving blades, driving them around—and so on. The areas of the passages increase progressively in volume, corresponding with the expansion of steam. They will, however, be described more fully later. On the right of the steam inlet are shown revolving balance pistons "P," "P " and "P ", one corresponding to each of the cylinders in the turbine, which according to size may be 1, 2, 3 or 4 in number. The steam at "A" presses against the turbine and goes through doing work. It also presses in the reverse direction, but cannot pass the piston "C," but at the same time the pressure, so far as the steam at "A" is concerned, is equal and opposite, so that the shaft is not subjected to any end thrust.

By reason of balance ports "E," so far as the steam pressure is concerned, there is no end thrust.

The areas of the balance piston are so arranged that no matter what the load may be, or what the steam pressure or

Westinghouse-Parsons Turbines, Continued.

exhaust pressure may be, the correct balance is preserved and the shaft has no end thrust whatsoever.

The thrust bearing but serves only to maintain the correct adjustment of the balance pistons. It is in two halves the lower half capable of adjustment in one direction, the upper one in reverse.

The balance pistons never come in mechanical contact with the cylinder, and consequently there is no friction. The thrust bearing has ample surface, and besides is subjected to forced lubrication and does not wear. The adjustments once made always remain good.

The bearings are unique in construction. The bearing proper is a gun metal sleeve, which is prevented from turning by a loose fitting dowel. Outside of this are three concentric tubes having a small clearance between them. This clearance fills up with oil and permits a vibration of the inner shell, at the same time restraining same. The shaft, therefore, revolves about its axis of gravity, instead of the geometric axis, as would be the case were the bearing of every-day construction. The journal is thus permitted to run slightly eccentric, according as the shaft may be out of balance. This form of bearing in a very remarkable manner performs the functions of De Laval's slender flexible shaft. But in this case the shaft is built as rigidly as possible, so is not liable to crystallization, which would result in eventual rupture.

The power of the turbine is transmitted by means of a flexible coupling. Either machine may thus be dismantled without disturbing the remaining adjustments.

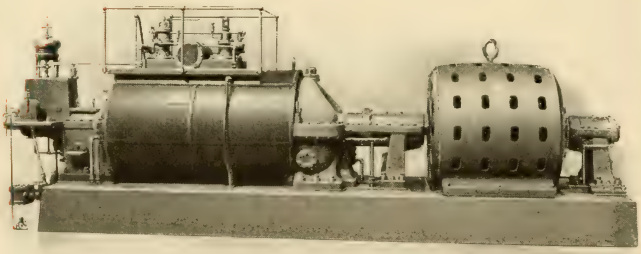
The governor gear and oil pumps generally receive their motion by means of a worm wheel gearing into a worm cut on the outside of the coupling.

There is an oil reservoir into which drains all the oil from the bearings. From there it runs into a pump to be pumped up to a chamber where it forms a static head which gives a continuous pressure of oil to the bearings. The pump is single acting of the simplest possible construction, that will not become deranged. The oil runs in by gravity, so that it is unlikely to fail to continue pumping.

Frictionless glands are provided at the ends of the casing or stator to prevent the escape of steam or the influx of air into the turbine at the point of entry of the shaft. Air leakage is particularly detrimental in cases where it is desirable to maintain a high vacuum. The water sealed glands used in the Westinghouse-Parsons turbine, effectively prevent this leakage, and, further, require no lubrication. It is impossible for any oil from the bearings or the lubricating system to

Westinghouse-Parsons Turbines, Continued.

(Westinghouse-Parsons Turbine-Generator Unit of 1,000-Kilowatt rated capacity as it appears when installed.)



(Rear view of same machine. These views illustrate the self-contained construction of the turbine generator unit, complete in every detail, as erected and tested in the shops. In the form shown the unit is ready to be placed upon its permanent foundation in complete operating condition at the purchaser's power plant.)

Westinghouse-Parsons Turbines, Continued.

find its way into the steam spaces. There are no rubbing surfaces in these glands, and experience has demonstrated that wear is negligible. The water used for sealing them is small in quantity and is not wasted, as, after serving its purpose, it may be returned to the feed water system.

The rotating element is built up of cast-steel drums carrying rows of blades or vanes, these being mounted on a steel shaft. These drums are arranged in three steps of increasing diameters, but the selection of three diameters is merely for mechanical convenience. Provision for the proper expansion of the steam might be made, whether there be one or several diameters. If, however, a speed and diameter of rotor be selected that would permit of a convenient size of blades at the outlet, those at the inlet would become inconveniently small, and vice versa. By varying the drum diameters at several convenient points, the proper velocity relations between steam and vane may be preserved, and at the same time the number of different sizes of blades may be reduced to a minimum.

Opposed to the three sets of blades the spindle also carries three rotating balance pistons P, each of such diameter as to exactly balance, by means of the passages E, the axial thrust of the steam against its corresponding drum of blades. These balance pistons revolve within the cylinder with a close fit but are not in mechanical contact. The adjacent surfaces are provided with frictionless packing rings which offer so devious a path for the steam as to make leakage past them inappreciable. The shaft also carries a small thrust, or, more properly, adjustment bearing, whose sole function is to maintain the normal mechanical clearances between the rotating and stationary blades. These clearances may be conveniently large without lowering the efficiency. In actual practice they are never less than one-eighth inch, and in large blades are as much as one inch.

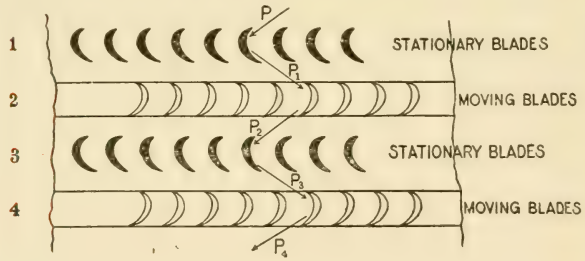
The interior proportions of the casing conform to the several diameters of the rotor and its parts. Around its inner surface are fixed rings of blades which alternate in position with the rings of revolving blades upon the rotor, and are of reverse pitch. The cylinder is divided along a horizontal plane so that by simply lifting the cover all the working parts are exposed to view.

The precise curvature and arrangement of the blades is the result of both theory and exhaustive experiment. The blades are so assembled as to admit of great ease of repair, and by a calking process which holds them so firmly to the body of the rotor that they will pull in two before they can be drawn out by force.

Westinghouse-Parsons Turbines, Continued.

The essential parts of the turbine are of course the blades and buckets. They are made of hard drawn material. They vary in size from ½ to 7 inches according to where they may be used. Every row of these blades has passages of increased area, corresponding with the volume of the steam. This increase of volume is obtained by increasing the heights of the blades and when these have reached their desired limit, the diameter of the turbine is increased and the steam permitted a higher velocity that enables the blades to recommence another progression. The blades are lashed together in each row in a most durable manner which effectually keeps them in their proper position.

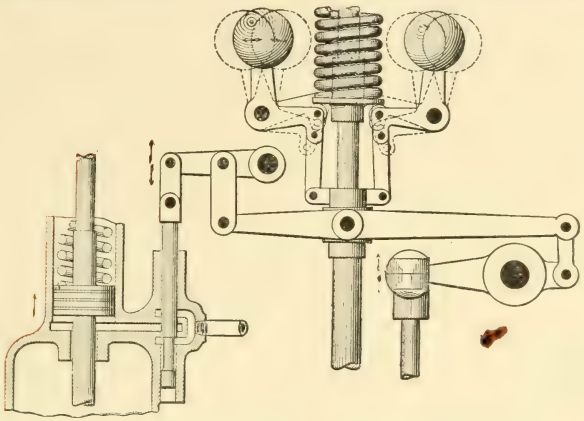
Considering one barrel of the turbine the fall of pressure, or, to be more exact, the co-efficients of expansion, are the same for every row.



Referring to above diagram the steam at pressure "P" in expanding through row 1 to pressure "P_1," converts its energy into velocity and impinges upon the moving blades row 2. The steam then performs a second expansion in expanding through row 2, again converting its energy into velocity, but this time the energy of the efflux is to react upon the blades from which the steam issues. The same cycle is repeated in row 3 and row 4 and so on until exhaust pressure is reached. The moving blades therefore receive motion from two causes, the one due to the impact of steam striking them, the other due to the reaction of the steam leaving them, and in this respect is this turbine a combination of Bianca's wheel and Hero's engine.

Many people suppose that these blades wear under the action of steam. Experience shows that they do not. In the case, however, of a nozzle, such as has already been described, in combination with the blades, the result is very different by reason of the tremendous velocity of the steam. The wear even then is not much when superheated steam is made use of, but with any entrained water, the wear is quite rapid.

Westinghouse-Parsons Turbines, Continued.



(Diagrammatic arrangement of Governor Mechanism.)

In the Parsons turbine the velocities of steam never exceed 500 to 600 feet per second, and for the most part are considerably less.

Steam enters the turbine in puffs, not in a continuous blast. Speed regulation is, therefore, accomplished by proportioning the duration of the puffs to the load. This is done by means of a small pilot valve actuated directly by the governor and which controls the steam supply through the main poppet admission valve. When the turbine is in operation the main poppet valve is continually opening and closing at uniform intervals, but the periods during which the valve is allowed to remain open are proportioned to the load on the turbine. At light load the valve opens for a very short period and remains closed during the greater part of the interval. As the load increases the period lengthens until finally, at about full load, the valve does not reach its seat at all and continuous pressure is obtained in the high pressure end of the turbine. On the load becoming further increased an auxiliary or secondary valve "P" begins to open and to admit steam through the port "D" to the annular space "E" at the beginning of the intermediate drum of the rotor where the working steam areas are greater. This increases in proportion the total power of the turbine. The operation of this secondary poppet valve is the same as that of the main admission valve, so that the governor automatically controls the power and speed of the turbine from no load to such overloads as are usually beyond the limits of generating

Westinghouse-Parsons Turbines, Continued.

apparatus built on normal ratings. The turbine also operates at its *best economy* at or near full rated load, although possessing at the same time large overload capacity with remarkably high efficiency.

The governor is of the fly-ball type, the ball levers being mounted on knife edges instead of pins to secure sensitiveness. The speed of the turbine while running may be varied within the limits of the governor spring by grasping the knurled hand wheel at the top, when the spring and tension nuts may be brought to rest. Adjustment of the spring tension may then be made. This feature is particularly useful for synchronizing the speed of alternating current generators, operating in parallel and for distributing the load between them when so operated. The figure above illustrates diagrammatically the connection between the governor and the pilot valve. Variations in the speed change the height of the fulcrum of the lever on the governor spindle, which in turn varies the throw of the pilot valve relatively to the valve port. This controls the main valve and steam admission as above stated. Reciprocating motion necessary to operate the mechanism originates in an eccentric driven by the turbine from a worm on the main shaft.

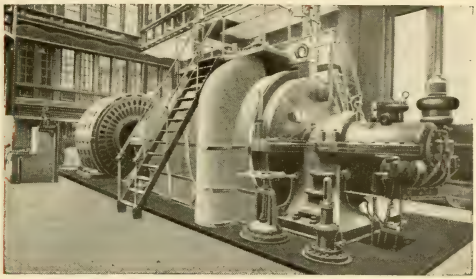
On all turbines an automatic centrifugal speed limit governor is provided which instantly shuts off the steam supply if a predetermined excess of speed above normal should be reached.

The difficulties experienced with lubrication and the destruction of valves and glands under high temperatures have limited the use of superheated steam with the piston type of engine. The turbine, however, has steam-proof frictionless glands and requires no internal lubrication. Its construction admits of the use of the highest superheat, and the steam may be expanded down to the lowest condenser pressure without the great increase in bulk and friction which renders the use of high vacuum ineffective in reciprocating engines. Higher economies are thus made possible in turbine work.

Reciprocating engines grow less economical as they age and wear. The Westinghouse-Parsons turbine retains its original steam economy through years of service. The adjustments do not change. There is nothing to wear out. The bearings are the only rubbing parts, but, being flooded with oil, the shaft never comes in metallic contact with the bearing. The blades retain their original shape, and the low steam velocities employed prevent the erosive action which accompanies the use of high velocity steam.

The Westinghouse turbine generator is of the revolving field type, with the rotor small in diameter and especially

Westinghouse-Parsons Turbines, Continued.



(Manhattan Power Station of the Interborough Company, New York City, showing the 5500 kilowatt Westinghouse-Parsons Turbine unit, capable of delivering 10,000 H. P. continuously.)

designed to facilitate ventilation and minimize windage. The standard construction of stationary laminated armature is employed and bar, strap or wire windings are used according to the voltage and capacity of the machine. Thorough protection to prevent mechanical injury is afforded by embedding the windings in partially closed slots in the laminated structure which is at the same time well ventilated by numerous air ducts communicating with openings in the outer frame.

For parallel operation of alternators a uniform turning moment or driving torque is of the utmost importance. The speed of the turbine is uniform at all parts of its revolution, which is not true of piston engines. This renders the turbine especially suitable for this purpose, and the synchronizing of A. C. generators is easily accomplished. Turbine-driven alternators parallel satisfactorily with those driven by reciprocating engines possessing good regulation, and in fact will usually favorably influence the operation of lighting circuits by steadying the engine-driven units.

The turbine has no reciprocating thrusts or vibrations to be absorbed. It does not need to be bolted to its support. Any foundation strong enough to maintain alignment and bear the weight is sufficient. For this reason much less foundation material is necessary than would be required for reciprocating engines. Hence it may be installed on floors or on galleries if necessary.

Westinghouse-Parsons turbines are shipped with all the main parts assembled and permanently adjusted. Where weeks or months are required to erect a piston engine, the turbine requires but a comparatively few days. Actual ex-

Westinghouse-Parsons Turbines, Continued.

amples are not uncommon where 600 horse-power Westinghouse-Parsons turbines have been supplying commercial current within less than a week from the time of delivery.

These generator efficiencies are well up; even the 400 K. W. and 750 K. W. showing 89% at one-half load, 92¼% at three-fourths load, and 93¾% at full load.

Condensers for Turbine Work.

In connection with cooling towers, when a sufficient source of water is not otherwise obtainable, there is no excuse for running steam turbines non-condensing, for the economy is so much greater condensing than non-condensing. This is due to the fact that turbines can expand down to the utmost limit of exhaust pressure that is commercially possible to obtain. High vacuum is not absolutely necessary, but the higher the vacuum the better the economy. Approximately each inch of vacuum beyond 26" will benefit the economy from three to four per cent. With air leaks eliminated and a closed hot well system, the air pump should take no more power because of a high vacuum; therefore the cost of the additional apparatus for maintaining the high vacuum only need be considered, and the cost of pumping the additional amount of circulating water required.

An effective means of reducing the power requirements of a surface condensing plant is to balance the circulating water columns leading to and from the condenser by sealing both ends beneath the same level of water. A syphon is thus formed, and it is only necessary to move the circulating water against the friction of pipes, valves and condenser tubes.

Surface condensers will probably be more frequently employed in connection with turbines than other types, if only because of the advantage of absolutely clean feed water.

It is claimed by condenser builders that with modern dry vacuum pumps, and a closed hot well system, that a better vacuum can be obtained than with a jet condenser, due to the fact that the feed water does not become aerated.

The cost of operating a surface condenser can, under favorable conditions, be kept very small, especially when the circulating water does not have to be raised to any height.

A jet condenser, on the other hand, has to do work in order to expel the cooling water against nearly an atmospheric pressure, according to the vacuum; but is a considerably simpler piece of apparatus, is less costly and is generally not subject to electrolytic troubles that are sometimes incidental to surface condensers.

Westinghouse-Parsons Turbines, Continued.

Barometric condensers make a very suitable type of condenser for large vertical engines, especially when the steam can get direct to the condenser without having to be carried upward.

With turbines, in connection with this type of condenser, some work is required to carry the water in the exhaust steam to the top of the condenser.

No particular type of condensing apparatus is recommended though several different types are shown in the different installations illustrated on subsequent pages.

Referring again to the desirability of high vacuum (which is emphasized by the tables showing Performance and Economy Tests that follow), I herewith append table which will be found interesting:

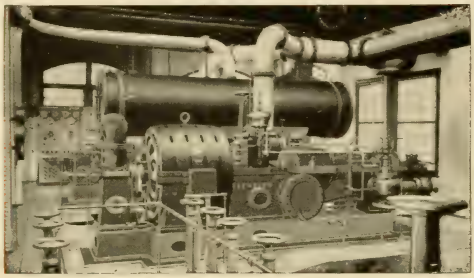
Relative Economy of High Vacuum.

Conditions of operation	Good Coal Continuous Service.	Med. Coal Continuous Service.
Capacity plant.....Kw.	2,000	2,000
Daily run.....Hrs.	24	24
Yearly run.....Days	365	300
Average load.....Kw.	1,500	1,000
Price coal.....per ton (2,000 lbs.)	$1.00	$2.00
Evaporation (actual).....Lbs.	9½	8
Average economy..Lbs. water per Kw. hr.	23	22
Raise vacuum.....Inches	26 to 28	26 to 28
Water saved per Kw. hour.....Lbs.	1.84	1.76
Water saved per day.....Lbs.	66,240	42,240
Coal saved per day.....Tons	3.49	2.64
Gross saving per day.....	$13.96	$5.28
Gross saving per year.....	$5,095.	$1,584.
*Extra cost of condenser.....	$4,000.	$4,000.
Interest 5%, Depreciation 7½%.....	$500.	$500.
Net saving per year.....	$4,595.	$1,084.
" " " " Capitalized at 5%.....	$91,900.	$21,680.
**Net saving as interest on increased investment in 2" extra vacuum.....	114.9%	27.1%

*This cost is being constantly reduced through improvements in condensing apparatus.

**Saving in cost of feed water and loss due to increased power requirements are not included in this estimate.

Westinghouse-Parsons Turbines, Continued.



(The above cut shows a surface condenser above the engine room floor and just back of the turbine, the pumps only being located in the basement beneath. This arrangement is not best practice, however.)

Power Required for Condensing Auxiliaries.

Whether the auxiliaries are to be motor-driven or steam-driven, it is a matter of a good deal of concern to know about what percentage of power is to be allowed for condensing apparatus. The only data we have on that is one test made at the plant of the Citizens Light, Heat & Power Company, Johnstown, Pa. The following table shows the performance of the condensing apparatus for a pair of 400 K. W. Westinghouse-Parsons turbines. The condenser in this case is a barometric condenser, with steam-driven dry air vacuum pump and an engine driven rotary circulating pump. The exhaust steam from these auxiliaries is used for heating boiler feed water by discharging into an open heater.

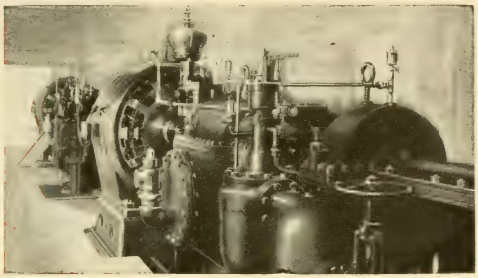
Test of Power Consumption of Auxiliaries.

Load.		Vacuum.	I. H. P. Auxiliaries.			Per Cent. Total Power.		
E. H. P	I. H. P.	Inches, Hg.*	Steam Cylinder.	Air pump.	To water, pump	Steam cyl., %.	Air cyl., %.	To water, %.
97.8	150.8	27.8	7.08	2.45	4.63	4.7	1.63	3.07
167.5	220.5	27.7	7.75	3.00	4.75	3.5	1.36	2.14
185.0	238.0	27.6	7.66	3.02	4.64	3.22	1.27	1.95
207.5	260.5	27.6	8.38	3.16	5.22	3.21	1.21	2.00
238.0	291.0	27.3	8.98	3.46	5.52	3.09	1.19	1.90
241.0	294.0	27.4	8.75	3.21	5.54	2.98	1.09	1.89
404.0	457.	....	12.77	4.35	8.42	2.8	.95	1.85
536.0	589.	..	14.57	5.03	9 54	2.47	.85	1.52

*Referred to 30-inch barometer.

Turbine Indicated horse-power based upon no load losses, which are assumed approximately constant throughout the test.

Westinghouse-Parsons Turbines, Continued.



Economies of Turbines.

As for the economies of turbines, I simply append table showing the performance of an average size turbine (750 K. W.) with the remark that even in the smaller sizes these results will be approximately obtained, and in the larger sizes they will be slightly bettered.

Test of 750 K. W. Turbines, Built for Boston Navy Yard and Manila Tramways.

Load, B. H. P.	Steam Pressure, lbs.	Vacuum, Inches.*	Super-heat, °Fahr.	Speed, R. P. M.	Water per Hour, lbs.	Steam Consumption per B. H. P. Hour.
354.96	154.7	28	100.11	1,791.7	5,439	15.32
712	150.8	28.07	102.62	1,797.5	9,450	13.27
1,151.1	151.4	28.01	99.07	1,804.35	13,808.4	12.38
1,554.3	150.9	27.85	99.72	1,787.8	20,202.4	12.99
2,146.78	150.7	26.42	92.9	1,769.8	29,874	13.91
520.1	151.4	27.89	153.7	1,829.4	7,194	13.85
1,066.5	148.6	27.99	153.9	1,827.4	12,580	11.79
1,345.8	149.9	27.99	152.2	1,807.8	15,370	11.42
1,529.3	149.2	27.76	153.5	1,792.9	17.592	11.50
761.06	153.5	.....	93.94	.....	18,303	24.06
1,544.56	149.2	.....	85.33	.....	36,248	23.46
811.04	149.8	28.01	2.34	.. ...	11,779	14.49
1,126.1	149.5	27.97	2.54	.....	15,506.8	13.77
1,074.7	190.1	.....	7.18	.....	3,037.1	28.26

*Vacuum referred to 30-inch barometer—sea level.

Note.—Though it is true that turbines can be designed for non-condensing work to show a very fair economy, this practice is not to be recommended, nor, as already stated, is it a reasonable and good commercial proposition. It is also to be noted that turbines designed for condensing will not operate non-condensing with quite as good economy as if designed to operate that way. When a turbine is designed for condensing work and run non-condensing, the steam consumption is somewhat less than double the condensing water rate.

Westinghouse-Parsons Turbines, Continued.

Even after deciding upon the use of turbines and the sizes of the units desired and their electrical characteristics, purchasers are often perplexed in deciding upon the most desirable characteristics for the steam end of the machines.

The following tables, therefore, will no doubt be found interesting and of some assistance:

The first one refers specifically to steam pressures, superheat, and vacuum, showing the best practice in these respects, as illustrated in the equipment of forty-six plants. It will be noted that these results are given both in percentages of the total number of plants and in percentages of the total capacity of the plants.

In the second table it will be seen how the sizes of units relatively affect some of the principal engineering features of the lay out.

Data on Turbine Plant Equipment.

Pressure.				Superheat.				Vacuum.			
No. plts.	Per cent. Plants.	Per cent. Capacity.	Pressure lbs. per sq. inch.	No. plts.	Per cent. Plants.	Per cent. Capacity.	Superheat, deg. Fahr.	No. plts.	Per cent. Plants.	Per cent. Capacity.	Vacuum, inches.
34	79.	61.	150–175	17	37.	39.8	100–150	21	45.6	44.9	27–28
5	10.9	32.3	175–200	4	8.7	33.4	150–200	7	15.2	37.3	26–27
6	13.	6.5	125–150	21	45.6	20.2	0	16	34.8	14.1	28
1	2.2	0.3	200	4	8.7	6.6	0–100	2	4.3	3.7	26—
			125—								

Data on Turbine Plant Arrangements.

Normal capacity of units ..... Kw.	400	1,000	5,500
Number of units	4	4	4
Capacity of room .. .. Kw.	1,600	4,000	22,000
Size of engine room..... .... Ft.	26 x 35	59 x 36	100x61
Length of turbine units (over all).....	18′ 11″	29′ 11″	47′ 3″
Width of turbine units (over all)..... ...	3′ 11″	5′ 3″	14′ 0″
Height of turbine units (over all).....	7′ 6″	8′ 4″	14′ 0″
Center to center distance between units..	7′ 10″	13′ 0″	22′ 6″
Width of passage ways..... ..... Ft.	4′ 0″	8′ 6″	8′ 6″
Depth of basement	14′ 6″	18′ 0″	25′ 0″
Vacuum .... In.	28	28	28
Condenser cooling surface.... ..... Ft.	7,000	16,000	80,000
Condenser cooling surface, per unit ..... Ft.	1,750	4,000	20,000
Condenser cooling surface, per kw . ..... Ft.	4.37	4.00	3.14
Area of operating room.....Sq. Ft.	910	2,124	6,100
Turbine capacity, per sq. ft. of operating room..... .....Kw.	1.76	1.88	3.60
Area of engine room, per kw. capacity....	0.57	0.531	0.277
Area of engine room, per E. H. P. capacity	.425	.396	.207

Westinghouse-Parsons Turbines, Continued.

Table of Standard Sizes,

Showing Approximate Dimensions, Speed, Etc.

Turbo-Generator Units.

Size in Kw.	Maximum Dimensions, in feet and inches.				Pipes, in inches.		Revolutions per minute.	Current required to excite at 125 V.
	Length.		Width.	Height.	Steam.	Exhaust.		
	Low Voltag's —2,200 Volts and under.	High Volt's —above 2,200 Volts.						
300	19-1	19-7	4-5	6-6	4	18	3600	45
500	21-3	21-9	4-5	6-9	5	22	3600	100
750	30-3	30-9	6-4	8-4	6	28	1800	125
1000	31-4	32-1	6-4	8-4	6	30	1800	180
1500	34-4	35-4	7-0	9-4	8	36	1200	200
2000	35-5	36-5	7-10	9-4	9	36	1200	300
2500	37-1	38-1	7-10	9-4	10	42	1200	350
3000	37-10	38-10	7-10	9-4	10	42	1200	400
5000							720	
6000							720	
7500							720	
10000							720	

Notes.—The above machines are of the standard sixty cycle type (7200 alternations); machines of other cycles built as desired. Generators are either single or polyphase and of any voltage.

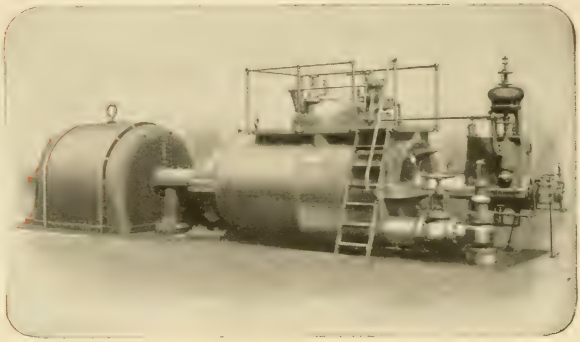
The 400 K. W. size has been heretofore built, but finding so little call for it, it has been dropped from the list of standard sizes.

While the list of sizes are referred to as standard, it is simply given so for the sake of convenience; there are a number of intermediate sizes that can be furnished when desired. Those given above with approximate dimensions, however, will furnish all the data necessary in cotton mill work, which is the trade for which this table has been especially compiled.

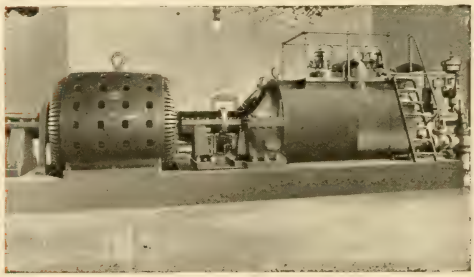
While the above machines are rated at their capacities as given, they are all capable of continuously maintaining 25 per cent. overload, and a 50 per cent. overload for a short time, and even higher overloads momentarily. The ratings may be maintained with pressures of 100 pounds and upwards, but it is, of course, understood in ordering turbines that all the characteristics be stated when making the original inquiry. All standard machines are constructed to maintain their rating on the governor up to 50 per cent. overload; anything over this is taken care of by the automatic by-pass. Bracket construction for direct connected exciters can be furnished, if desired, but it is not by any means recommended; on the contrary, the exciter should be independently driven.

Westinghouse-Parsons Turbines, Continued.

Sample Installations in the South.



(The above cut illustrates a 750 K. W. unit now in process of erection and installation for the Winston-Salem Power Co., Winston-Salem, N. C. This is the first unit of an ultimate equipment that is designed to consist of four such machines. A cut of their power house, with floor plan and section, appears in Vol. III.)



(The above cut represents a 1500 K. W. unit now in operation at the Pelzer Mfg. Company, Pelzer, S. C., to supplement their water power electric plant. A cut of their turbine power house with floor plan appears in Vol. III.)

Westinghouse-Parsons Turbines, Continued.

The generators illustrated in the foregoing cuts, except the one shown on top of page 926, are known as the—

Open Type Generators.

Machines of this type already installed in the South are:

	B. H. P.
Athens Electric Railway Co., Athens, Ga.	750
Consolidated Rys., Light & Power Co., (two), Wilmington, N. C.	1200
Gray Mfg. Co., Gastonia, N. C.	450
Gulfport & Miss. Traction Co., (two), Gulfport, Miss.	1500
Henrietta Mills, Henrietta, N. C.	600
Lake Charles Ice, Light & Water Works Co., Lake Charles, La.	600
Pelzer Mfg. Co., Pelzer, S. C.	2250

It will be noticed that the generator shown on top of page 926 is of the—

New Inclosed Type Generators,

which is now the standard type of generator in use in Westinghouse-Parsons turbo-generator sets.

This new type of generator practically does away with all noise, so that our customers who now have them in operation speak of them as "noiseless."

Ventilation is provided for by an air duct in which cool air is brought from outside the building through a galvanized iron duct underneath the floor to the base of the generator.

Some of the recent installations with this type of generator in the South are:

	B. H. P.
Brown Mfg. Company, Concord, N. C.	450
The Sheffield Co., Sheffield, Ala.	1500
Modena Cotton Mills, Gastonia, N. C.	450
Lumberton Cotton Mills, Lumberton, N. C.	450
Winston-Salem Power Co., Winston-Salem, N. C.	1125
Durham Traction Co., Durham, N. C.	750
Atlantic Coast Line Ry., (two), Waycross, Ga.	900
Columbia St. Railway, (two), Columbia, S. C.	4500
Phosphate Mining Co., (two), Lakeland, Fla.	1500
Francis Cotton Mills, Biscoe, N. C.	450

Westinghouse-Parsons Turbines, Continued.

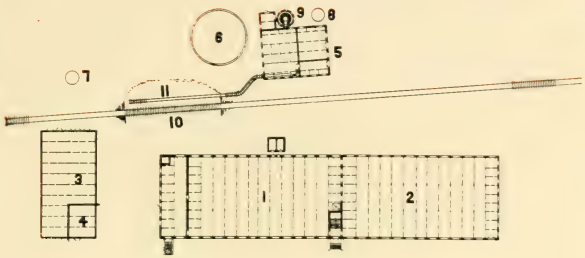
Gray Mfg. Company, Gastonia, N. C.

Stuart W. Cramer, Engineer.

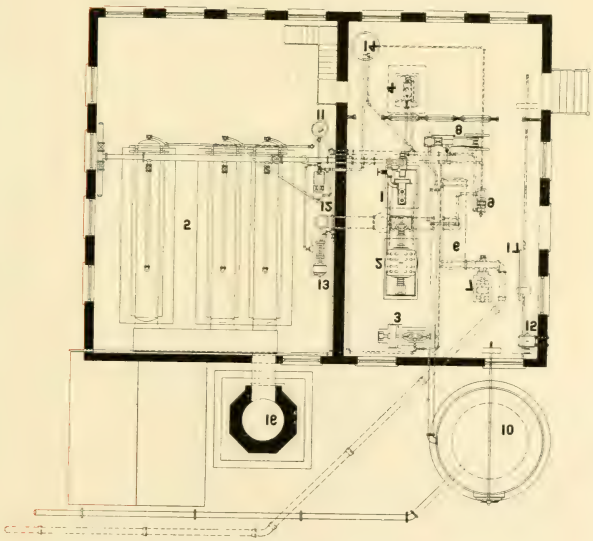
The above cut illustrates the new fine yarn mill of the Gray Manufacturing Co., Gastonia, N. C. This plant is unique, not only because it is proposed to spin the finest yarns yet spun in the South, viz., 80's to 100's combed Sea Island and Egyptian yarns; but also because it is one of the few mills specially laid out for a turbine drive.

The cut on the top of the opposite page shows a plot of the property:

(1) and (2) Main Mill and its extension. (3) Cotton Warehouse. (4) Opening Room. (5) Power House. (6) Reservoir. (7) Elevated Tank. (8) Cooling Tower. (9) Stack. (10) Coal Chute. (11) Coal Haulage Track.



Plot (See opposite page).



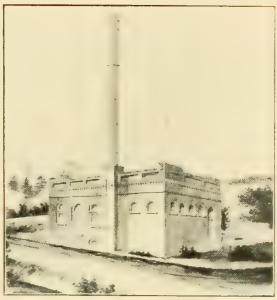
Plan of Power House.

(1) Westinghouse-Parsons Steam Turbine. (2) Turbo-generator, 60 cycles, 3-phase, 440 volts. (3) Steam Driven Exciter Set. (4) Automatic Engine driving Centrifugal Pump. (5) Babcock & Wilcox Water Tubular Boilers with Superheaters. (6) Alberger Surface Condenser. (7) Centrifugal Circulating Pump. (8) Dry Vacuum Pump. (9) Hot Well Pump. (10) Alberger Cooling Tower. (11) Feed Water Heater. (12) Worthington Boiler Feed Pump. (13) Electric Driven Boiler Feed Pump. (14) Hot Well. (15) Motor driving cooling tower fan. (16) Brick Stack. (17) Switchboard.

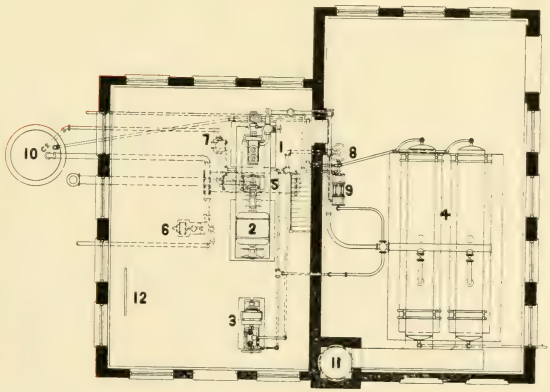
Westinghouse-Parsons Turbines, Continued.

Brown Manufacturing Co., Concord, N. C.
Stuart W. Cramer, Engineer.

The above cut and that on the opposite page illustrate the mill and power house respectively of the Brown Mfg. Company, at Concord, N. C. The mill is located about a mile from the power house up on high ground overlooking the town, a most excellent situation not only for light and ventilation about the mill, but also an admirable location for the mill village. The power plant, on the other hand, is located down in the hollow near the railroad station, by the railroad, adjacent to a splendid water supply. In making this disposition of his buildings, Mr. C. W. Johnston, the President, was guided largely by his experience in electric driving at his Highland Park Mfg. Company's mills, full and complete description of which appear in Vol. III.



Power House of Brown Manufacturing Co.



Plan of Brown Manufacturing Co's. Power House.

The installation consists of:
(1) 300 K. W. Westinghouse-Parsons Steam Turbine. (2) 300 K. W. Turbo-generator, 60 cycles, 3-phase, 2300 volts. (3) Steam Driven Exciter Set. (4) Babcock & Wilcox Water Tubular Boilers. (5) Worthington Surface Condenser. (6) Circulating Pump. (7) Dry Vacuum Pump. (8) Feed Water Heater. (9) Worthington Boiler Feed Pump. (10) Hot Well. (11) Stack. (12) Switchboard.

Note.—The Francis Cotton Mills power house and power equipment is practically the same as this one.

Westinghouse-Parsons Turbines, Continued.

The Henrietta Mills, Henrietta and Caroleen, N. C.

The above cut shows the No. 1 Mill at Henrietta on the right, and the No. 2 Mill at Caroleen on the left. In the No. 1 Mill we have recently installed a 500 K. W. turbo-generator installation to supplement their water power, the water powers all through the Carolinas as well as elsewhere in the country having partially failed during the last few years on account of the cutting away of timber and other changes in the topography of the neighboring water sheds.

The Henrietta plant is one of the largest in the country, both the No. 1 and the No. 2 Mills being driven direct both by water power and supplemented by steam power from engines through the medium of belts and ropes. The new power, however, takes the form of an electric drive, the power being distributed either at the No. 1 or the No. 2 Mill (a mile and a half apart) according to their varied requirements,—the results being most satisfactory.

The condensing apparatus in this plant also is of the barometric type, by Bulkley. The exhaust from the steam end of the condenser pump is used to heat feed water. There is sufficient head of water available in the flume near by to operate this condenser without the use of the pump,—the pump only being used to start the flow of water, which afterwards continues by syphonic action.

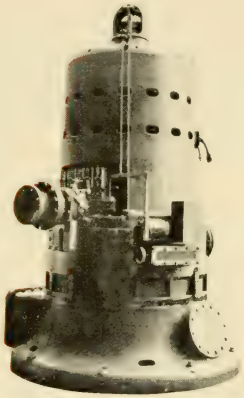
Westinghouse-Parsons Turbines, Concluded.

Stuart W. Cramer, Engineer. **Modena Cotton Mills, Gastonia, N. C.**

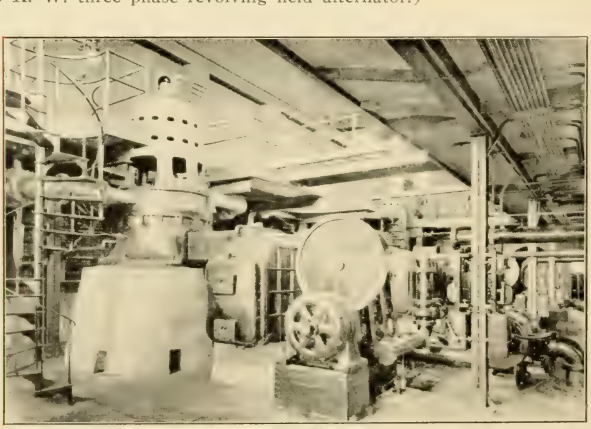
The above cut represents Modena Mills Nos. 1 and 2, both of which are direct steam-driven by belts, and the No. 3 addition electrically driven, the current being furnished by a 300 K. W. Westinghouse-Parsons turbo-generator. 220 volts, 3-phase, 60 cycles. The condensing apparatus was made by Wheeler, consisting of one of their latest type surface condensing outfits. The boilers are Babcock & Wilcox high pressure boilers, with wrought steel headers. The switchboard and motor equipment, are of the Westinghouse make, part of the motors driving direct on the line shafts and the others driving the counters.

The facility and ease with which cotton mills can be increased without additions to their power houses is shown in the case of this Modena Cotton Mills, the turbo-generator being located in a small but ample vacant space in the present engine room.

THE CURTIS TURBINE.



(The above cut represents a General Electric outfit, consisting of a two-stage vertical type Curtis steam turbine, direct connected to a 500 K. W. three phase revolving field alternator.)



(This reduction from a photograph shows one of these same 500 K. W. Curtis turbine installations in the Newport station of the Newport & Fall River Street Railway Company,—complete, including a general view of the basement, with condenser, pumps, etc., in the foreground.)

The principles of the De Laval and the Parsons turbines

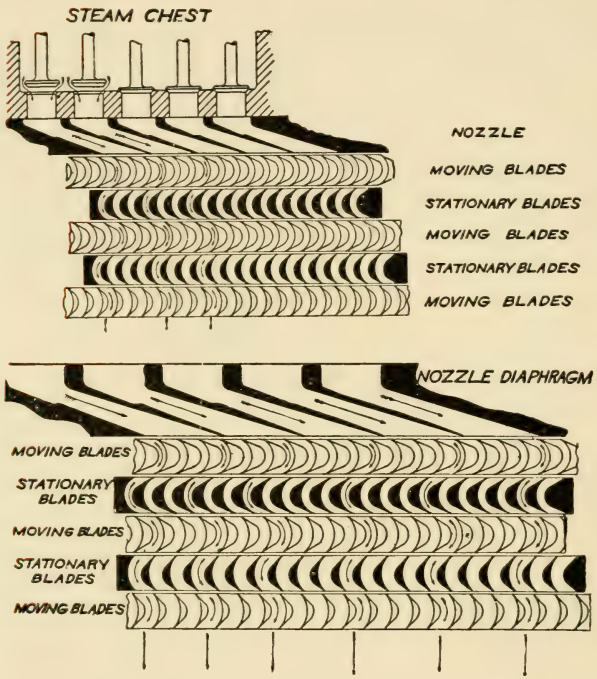
Curtis Steam Turbines, Continued.

have already been explained. The Curtis turbine, introduced by the General Electric Company, was designed to secure a machine primarily of lower speed than the other types. It is proper to state, however, that while the rotating speed is less than the other types, owing to the diameter of the wheel, the peripheral velocity is as great if not greater than the other types. Therefore, it would seem that this claim has not been borne out by the facts. It is a fact, however, that in positions where the location is such that a vertical type is preferable, the Curtis turbine is admirably adapted, for it is exceedingly compact and economical in space.

This turbine is divided into stages, each of which may contain one, two, or more revolving buckets supplied with steam from a set of expansion nozzles. The work is divided between several stages, consequently the nozzle velocity in each stage is reduced, thereby rendering the nozzle action more efficient and perfect than it can be where a higher initial velocity is imparted. Under this arrangement the energy of the moving steam is effectively given up to the revolving part. The division of pressure between the stages is so arranged as to utilize the largest possible proportion of the energy of expansion. The position of the moving and stationary buckets with relation to the nozzle is shown in the diagram on the following page.

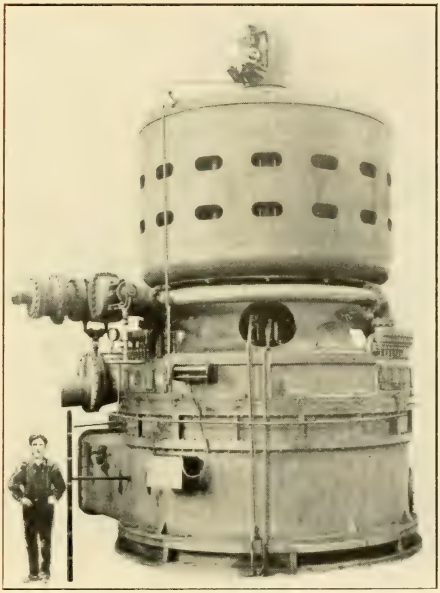
As already stated, the Curtis is a vertical type of machine and possesses certain special advantages for certain locations. This very fact of its being of the vertical type, however, raises some grave problems, such as providing a suitable and reliable step bearing and the maintaining of the vertical shaft in such position that its axis of rotation is coincident with its geometrical axis—a condition that is absolutely necessary on account of the minimum of clearances permissible on account of economical reasons in machines of this type. These problems have already been handled by the General Electric Company in a manner that excites admiration, and it is believed to be only a question of time until these have been entirely and satisfactorily disposed of. The step bearing at the end of the vertical shaft supporting the weight of the revolving part and maintaining the revolving and stationary elements in exact relation, is carried on a film of lubricating fluid; if the flow of oil is interrupted, it is said that the bearing is slowly worn away, but experience has shown that interruptions in the flow seldom take place, and that after the flow is re-established the tendency of the bearing is to wear itself to a new sur-

Curtis Steam Turbines, Continued.



face to operate normally again. In large stations where several turbines are operated, it is desirable to install weighted accumulators that will maintain a constant oil pressure and also act as a reserve. The Curtis turbine is operated by changing the number of the nozzle sections in flow and the efficiency of the machine is therefore claimed to be about the same under one condition of load as another, except that friction, windage and generator losses tend to slightly reduce the light load efficiency,—the same is said to be true of the overload efficiency. The speed of these turbines with variable load is controlled by the automatic opening and closing of the original admission nozzle section, and the number of nozzle sections correspond to the load always being kept in flow. A centrifugal governor attached to the top of the shaft imparts motion to levers, which in turn

Curtis Steam Turbines, Continued.



(5000 K. W. Curtis Steam Turbine, Direct connected to ATB-6-5000-500-9000 Volt Form T Generator.)

work the valve mechanism. There are a number of valves, each communicating with a single nozzle section, or, in some cases, two or more nozzle sections. These valves are connected to long pistons by which the valve can be opened or closed by steam. The motion of each of these pistons is controlled by a small pilot valve, which is worked by the governor mechanism. The movement of the governor mechanism moves the pilot valve successfully and the main valves are opened or closed by the steam. It is proper to state that the electrically operated valve mechanism, with its controller and rheostat, has been greatly improved since originally put on the market.

All that has been said about steam pressure, vacuum, and superheat, in other types of turbines, applies equally well to the Curtis turbine.

Curtis Steam Turbines, Continued.

Economies.

Mr. Geo. H. Barrus, of Boston, conducted series of tests on a two-stage 500 K. W. Curtis turbine installed in the Old Colony Street Railway Company. A summary of these tests, which we herewith append, may be accepted as a fair index of the work for all sizes of Curtis turbines.

Summary of Commercial Runs.

	Jan. 15,	Jan. 26,
Duration hours	12.22	15
Total coal wet, lb.	13,517	10,206
Moisture in coal, per cent	3.1	6.4
Water evaporated, lbs.	127,267	102,846
Drip withdrawn from steam pipe per hour, lbs.	.....	46
Moisture by calorimeter, per cent.	3.05	2.1
Total steam to turbine, lbs	110,084	86,833
Steam per hour to turbine, lbs	9,008.6	5,789
Dry steam per hour to turbine, lbs	8,733 8	5,667
Load by Polyphase meter, K. W.	407.0	234.7
Load on auxiliaries (average), K. W.	14.9	18.5
Total load, average, K. W.	421.9	253.2
Dry steam per kilowatt-hour, lbs.	20 7	22.38
Dry coal per kilowatt-hour, lbs.	2.54	2.51

Under the most favorable conditions of pressure, vacuum, and superheat, however, these results are bettered on the larger sizes, as will be seen from the following table showing tests made on a 2,000 K. W. turbine temporarily installed in the General Electric Company's power station at Schenectady.

Load in K. W.	Superheat, Degrees Fahr.	Vacuum, Inches.	Steam Gauge Pressure.	Pounds of Steam per hour per	
				Kilowatt	H. P.
637	215	28 2	150	20.1	15.00
1000	242	28.9	160	16.3	12 15
2000	242	28.73	155	15 3	11.42
2270	250	28.1	100	16 2	12.10

Sample Installation.

On pages 940-941, will be found a cut and diagram showing a Curtis steam turbine installed at The Lane Mills, in New Orleans. The old steam plant is done away with, and both the old and the new mills are now electrically driven from the new turbine plant, which, as will be seen from the diagram, consists of three Curtis turbines of 500 K. W. each.

Curtis Steam Turbines, Concluded.

General Electric Turbo-Generator Units,

Table of Standard Sizes and Approximate Dimensions, Speed, Etc.

Curtis Vertical Turbines, with A. C. Generators.

Size in K. W.	Stages	Dimensions, in feet and inches.		Main Steam Pipe.	Atmospheric Exhaust.	Poles.	Revolutions per minute.	Exciting Current Requir'd, Amp. at 125 Volts.
		Diameter of base.	Height.					
40 Cycles.								
1000						4	1200	100
2000						6	800	160
3000						8	600	200
60 Cycles.								
*100	2		4-2			2	3000	25
500	2	7-8	12-6¾	6	12	4	1800	75
1000	2	8-6	15-9			6	1200	105
1500	2	10-0	16-9¼	10	20	8	900	120
2000	2	11-2	19 3	10	24			150
3000	4	13-3	19-10½	12	30	12	600	200
5000	4	15-2	27-7	14	36	14	514	

*In the 100 K. W. size the over all dimensions are more than the actual floor space required by the base,—being 11′–2″ in length, 3′–8″ in width, and 4′–2″ in height. The actual base is 7′–4″ in length by 3′–3″ in width.

Notes.—The above are the tables of standard sizes of 40 and 60 cycle apparatus respectively, that have already been developed. Machines of other sizes and cycles built to order.

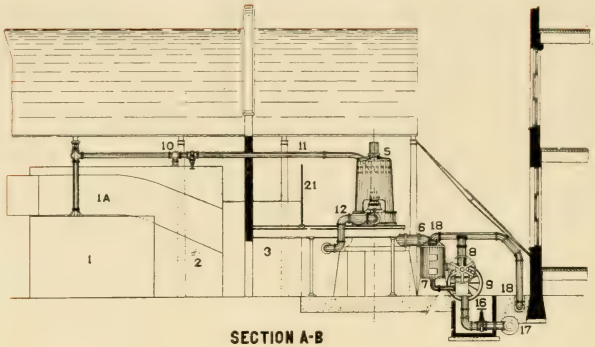
Voltages for 40 cycles, 2300 or less; for 60 cycles, 100 K. W., 2300 volts or less; 500, 1000 and 1500 K. W., 6600 volts or less; 2000, 3000 and 5000 K. W., 13200 volts or less.

Turbines may be built either two or three phase.

The atmospheric exhaust opening is of course for use when running non-condensing; the exhaust opening for connection to the condenser is greatly in excess of the atmospheric exhaust opening on account of the very high expansion permissible in steam turbines.

Curtis Horizontal Turbines, with D. C. Generators.

Size in K. W.	Approximate Dimensions, in feet and inches.			Main Steam Pipe, Inches.	Exhaust Pipe, Inches.
	Length.	Width.	Height.		
15	5-6½	1-10	2-2	2	3½
25	6-6½	2-7	2-7½	2½	4½
75	12-4	3-8½	6-6	3	8
150	16-7½	4-3	6-0	4	10



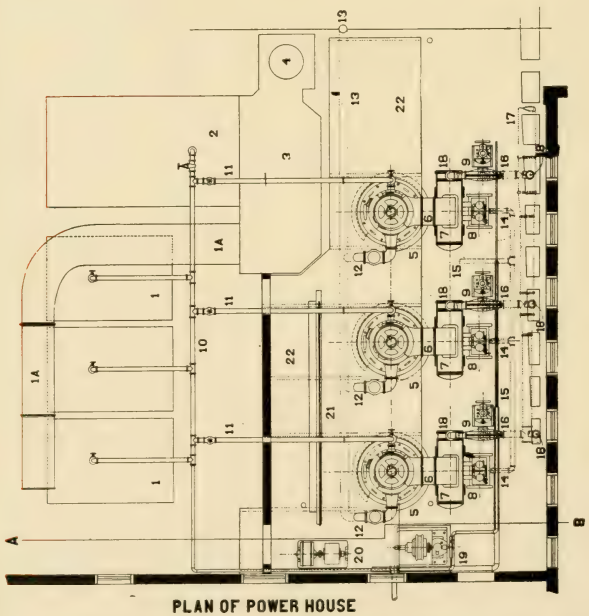
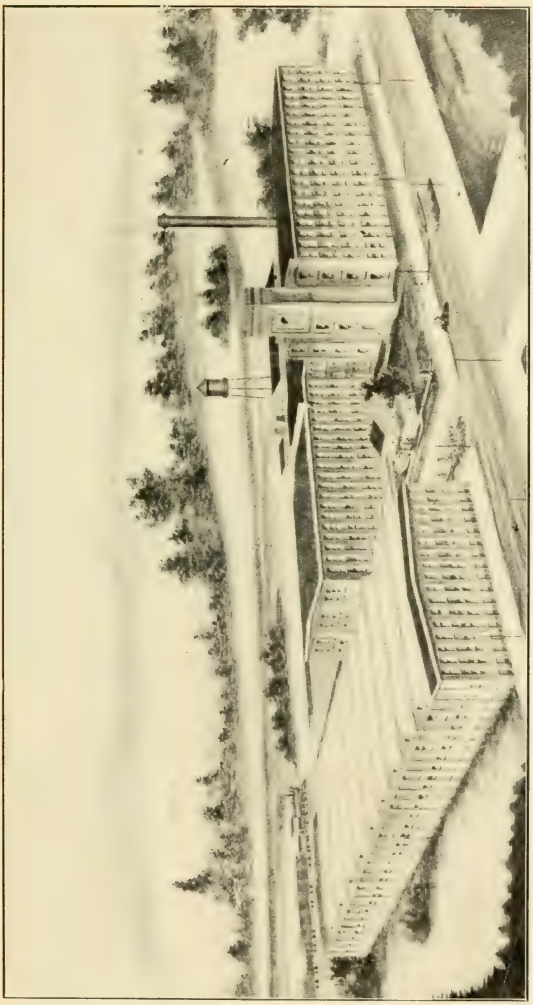


Diagram Showing Curtis Steam Turbine Installation at the Lane Mills, New Orleans.

(1) Three Marine Type Internally Fired Boilers. (1-a) Smoke Connection. (2) One battery Babcock & Wilcox type Boilers. (3) Green Fuel Economizers. (4) Stack. (5) Three 500 K. W. Curtis Turbines. (6) Exhaust

Curtis Steam Turbines, Continued.



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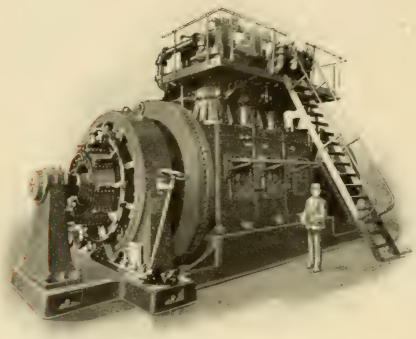
from same to Condensers. (7) Wheeler Surface Condensers. (8) Edwards Air Pump. (9) Steam Driven Centrifugal Circulating Pumps. (10) Steam Main. (11) Steam Branches to Turbines. (12) Individual Exhausts from Turbines to atmosphere. (13) Combined Exhausts from Turbines to atmosphere. (14) Individual discharge from Air Pumps. (15) Combined Discharge from Air Pumps. (16) Individual Inlets to Centrifugal Circulating Pumps supplying Injection to Condensers. (17) Water Service Main supplying Centrifugal Pumps. (18) Ejection from Condensers. (19) Steam Driven Exciter. (20) Motor Driven Exciter (Motor-Generator Set.) (21) Switchboard. (22) Engineer's Platform.

The Lane Mills, New Orleans, La.,
[Equipped by Stuart W. Cramer.]

F. P. Sheldon,
Mill Architect and Engineer.

WESTINGHOUSE GAS ENGINES.

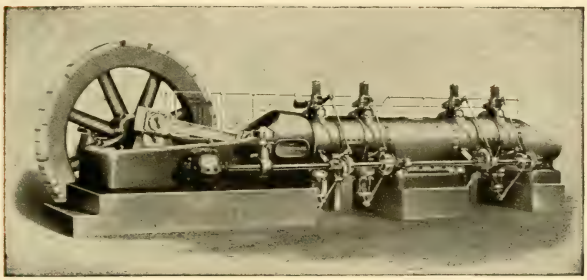


(550 Horse Power Westinghouse Vertical Single Acting Gas Engine, direct connected to D. C. Power Generator.)

These machines are built both vertical single acting and horizontal double acting. For many and evident reasons the single acting machine is chosen for light work, built with two cylinders in the smaller sizes and three cylinders in the medium sizes; the horizontal double acting machines are not built in single cylinder engines for commercial reasons, but are built in tandem for moderate sizes, and twin tandem for very large sizes. The vertical size ordinarily are 250 H. P. and under, and the horizontal machines are 250 H. P. and upwards,—6000 H. P. machines being the largest that the Company has heretofore built, though they are prepared to make them larger if desired.

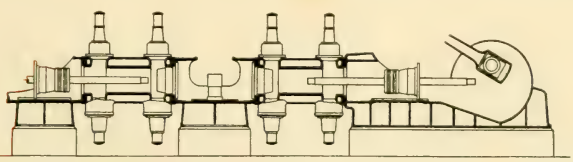
These machines can be used for driving line shafting, direct coupled to the crank shaft; for direct connection to electric generators; and with wheels for belts, ropes, or gearing,—in short, they are suited for any work which can be performed by any type of steam engine.

WESTINGHOUSE HORIZONTAL DOUBLE ACTING GAS ENGINES.



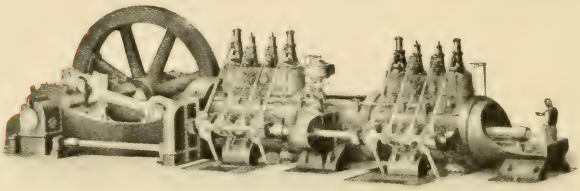
(The above cut illustrates the latest type Westinghouse Horizontal Tandem Double Acting Gas Engine, the same construction as is used in these engines from 300 to 3000 H. P. The twin tandem engines are similarly constructed, one engine connected to each end of the crank shaft, with the wheel between them; the power of such twin tandem engines is therefore simply double what the same sizes tandem engines would be.)

In the four-cycle double acting system of operation, two impulses are given to the crank shaft in each cylinder in two revolutions; so that, in the two-cylinder tandem engine there are four impulses in each two revolutions, and in the four-cylinder twin tandem engine there are eight impulses in each two revolutions. In other words, the distribution of power delivered to the crank shaft is for the two-cylinder gas engines the same as for an ordinary single cylinder double acting steam engine; and for the four-cylinder twin tandem double acting gas engine, the same as in a cross compound double acting steam engine with crank set at ninety degrees. The operation takes place at each end of each cylinder, or on the thoroughly proved "Otto" cycle, their sequence being the same as in the familiar single acting Otto gas engine.

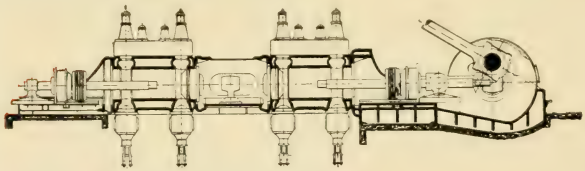


(The above diagram will make clear the extraordinary simplicity of the design of these engines to those who are familiar with the cumbersome, elaborate and inconvenient types of large machines heretofore on the market.)

Westinghouse Gas Engines, Continued.



(The above cut illustrates a well known type of horizontal tandem double acting gas engine of foreign design that has been adopted by a leading American engine builder. Note the great complexity of design and complication of its parts.)



(The above diagram, explanatory to the engine shown above, can be compared to a similar diagram of the Westinghouse engine on the bottom of the preceding page.)

Each end of the cylinder is therefore provided with two distinct valves, both positively operated: First, the inlet valve, admitting either air or explosive mixture into the cylinder; and second, the exhaust valve.

A comparison has already been invited between the new type Westinghouse horizontal double acting gas engine and those of older types and other makes now on the market, with particular reference to the type illustrated above with the accompanying explanatory diagram. This comparison is evident and speaks for itself. Returning, therefore, to the Westinghouse engine, and discussing it alone, it will be observed that all parts of it are entirely above the floor, easy of access, and always visible. Special means are provided for the handling of the valves with their bonnets so that the valves may be easily and quickly removed, reground if necessary, and replaced with a minimum of labor. The foundation is one solid block, and is not weakened by pockets or chambers to allow access to the valve gear, as has been customary in older types of horizontal engines already referred to.

It is also evident the ease with which the piston may be removed from the cylinder for the purpose of examination or for putting in new piston rings: the cylinder heads are merely loosened from their studs and slid along the piston without deranging the metallic packing in the stuffing boxes; the

Westinghouse Gas Engines, Continued.

connecting rod is uncoupled from the crosshead and swung clear; the piston rods uncoupled from their central crossheads and the piston withdrawn,—all without necessitating the breaking of any pipe joints or the disconnecting of parts which must be subsequently re-adjusted.

Regulation: The speed variation between no load and full load under running conditions would not exceed:

In two cylinder engines, 3% each way from normal.

In four cylinder engines, 2½% each way from normal.

The angular variation may, if necessary, be kept down to 2½ degrees of Phase Angle.

The speed regulation is fully equal to that of a high grade steam engine and is effected by patented arrangements of extreme simplicity. It is controlled by means of a regular fly-ball governor. Whatever the load, the total volume of gas and air drawn into the cylinder remains nearly constant, always completely filling the cylinder at atmospheric pressure. The air is never throttled during the suction stroke, and excessive losses as indicated by so many bottom-loop diagrams are thus avoided. The compression also remains constant for all loads, and the mixture even at the lowest under-loads never becomes sufficiently attenuated to produce risk of missfire.

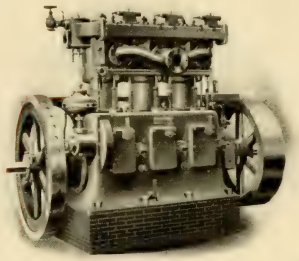
Starting Apparatus: For starting the gas engine, compressed air is generally advised, a small air compressor and air receiver for this purpose being used. In cases, however, where a direct current generator is coupled to the gas engine and suitable electric current is available from some outside source, the compressed air may be dispensed with and the engines started by driving the generator as a motor until after the first charge, compression, and ignition, when an automatic cut-off switch would throw the current out of the generator immediately upon same beginning to generate its own current.

Consumption of Cooling Water: Under usual conditions, this will be between ten and thirteen gallons per brake horse power hour. This may be reduced to 5% or 6% of the quantity by providing means to cool the water after use and return it again to the water jackets.

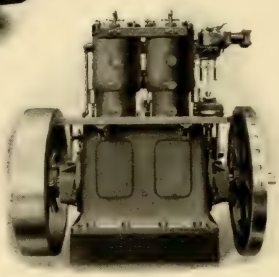
The cooling water should be as cold as possible and free from mud or scale-forming impurities, and should be delivered to the engine at about 50 lbs. per square inch. A small pump is furnished with the engine to deliver the circulating water to the pistons and piston rods under a pressure sufficiently high to insure the water column not being broken by the momentum imparted to the water resulting from the backward and forward strokes of the piston. If this is not done, a water hammer will result in the piston.

WESTINGHOUSE VERTICAL SINGLE ACTING GAS ENGINES.

The smaller vertical engines are rated on illuminating gas, but are also designed to receive cylinders giving equivalent horse power with producer gas.



(The accompanying cut shows the rear view of a 3-cylinder engine, with pulley for belt drive.)



(This cut illustrates front view of a 2-cylinder engine, also fitted with pulley for belt drive.)

The features peculiar to the Westinghouse vertical single acting gas engines may be briefly summarized as follows:

It employs a working cycle of maximum simplicity and efficiency, the four-stroke cycle.

Method of governing and the regulation secured suitable for driving electric generators for any service.

Self-contained construction; enclosed crank case employing constant and profuse oil bath lubrication.

Main bearings and reciprocating parts adjustable for taking up wear and maintaining original alignment.

Trunk pistons of special length, providing ample crosshead bearing surface.

Cylinders offset for reducing the angularity of the connecting rod on the power stroke.

Position of valves facilitating automatic cooling of exhaust valves and igniter.

Location of combustion chamber at the sides of the cylinder permitting ready removal of pistons without disturbing the valve mechanism.

All valve and igniter movements controlled by a single cam shaft

Westinghouse Gas Engines, Continued.

from which the governor is also driven.

Accessibility of all working parts; water jackets also accessible at many points for cleaning.

Starting simplified by the use of compressed air. Engine may be started in one minute.

Accurate efficiency tests conducted upon every engine before shipment.

Table of Standard Sizes of Westinghouse Belted Gas Engines.

Size of Cylinder		Natural or Illumination Gas Ratings.					
		Speed R. P. M.	Rated Brake Horse Power		Floor Space.		
Diam.	Stroke				Length	Width	Height
Horizontal Double Acting.							
			Tandem	Twin Tandem			
	24″	185	275–350	550– 700			
	30″	150	375–475	750– 950			
	36″	135	625–750	1250–1500			
	48″	100	1000–1200	2000–2400			
Vertical Single Acting, Two Cylinders.							
6″	8″	350	12		5′– 9″	Determined by diam. of largest wheel used	4′–4″
8″	10″	325	25		6′–10″		5′–4″
9″	11″	300	35		7′–10″		6′–0″
11″	12″	290	55		9′– 1″		7′–2″
13″	14″	260	85		11′– 1″		8′–5″
Vertical Single Acting, Three Cylinders.							
8″	10″	325	38		8′– 1″	Determined by diameter of largest wheel used.	5′– 6″
9″	11″	300	50		9′– 4″		6′– 0″
11″	12″	290	85		10′–11″		7′– 2″
13″	14″	260	125		13′– 1″		8′– 5″
14″	18″	240	175		14′–10″		9′–10″
15″	22″	225	210		15′– 6″		11′– 8″
18″	22″	200	280		18′– 2″		12′– 8″

Rating.—All of these sizes of engines are peculiarly fitted for direct connection to generators, for with this in view, their horse powers and speeds have been chosen to give desirable overloads with the regular standard sizes of generators. As already stated, these engines are designed to allow a certain variation in size of cylinders to give practically the same horse power with either natural, illuminating, producer, or blast furnace gases.

Westinghouse Gas Engines, Continued.

Economies.

Westinghouse gas engines are adapted to the use of all kinds of power gases. Moderate sizes of engines are also made for use with gasoline or other petroleum products.

The consumption of gas ranges from 11 to 12 cubic feet per brake horse power hour with natural gas of about 1.000 British thermal units calorific value to from 17 to 20 cubic feet with manufactured gas of about 650 British thermal units calorific value, according to the size of the engine and the exact heat value of the gas.

With producer gas the consumption varies also with the quality of the gas. Modern gas processes have recently been brought to such an efficient state that 80 or 85% of the original heat value of the fuel appears in the gas. The Westinghouse gas engine transforms *over* 25% of the heat energy of the gas into useful work at the shaft, whereas the corresponding efficiency obtained from an ordinary high grade condensing steam engine is seldom found to be more than one half of this figure. With producer gas, therefore, *fuel consumption would be 1 pound of coal per brake horse power hour*, or thereabouts, depending upon the quality. These results have readily been obtainable and are within reach of an engine of moderate size.

Performance of Westinghouse Gas Engine Brake Tests—East Pittsburg.

Engine		Calorific Value Gas B. T. U. per Cu. Ft 62 F 30 in. Kg.	Results						
			Overload		Full Load			Half Load	
Size	Type		B'hp	Cu Ft	B.hp	Cu Ft	B. T. U.	B.hp	Cu Ft
		(Pbg. Nat.)							
18x22	3-Cyl. Vert. Sing. Act'g	975	312	11.00	276.0	11.00	10,700	138.5	14 60
16x18	"	880	197	10.90	178.0	11.30	9.950	90.0	14.90
14x18	"	905	203	10.30	176.0	11.80	9,800	90.0	13.75
13x14	"	875	144	11.80	125.0	11.75	10,300	64.3	15.3
13x14	"	945	148	10.20	123.5	10.50	9,920	61.1	13.3
25x30	"	1000 (high)	666	10.01	553.1	10.45	10,450	37.5	13.40
15x22	"	960	254	10.10	219.0	10.50	10,008	112.0	15.00
18x22	"	950	320	10.60	280.0	10.90	10,350	142.7	14.70
11x12	"	860	96.1	11.40	85.7	11.40	9,800	43.8	14.10
28x22	"	1050	336	9.80	283.0	9.60	10.100	143.5	13.00
18x22	"	850	311	12.40	285.0	12.50	10,600	146.0	15.90
41x22	Horz. Doub. Tand.	870	293	12.10	251.0	12.10	10,500	128.5	15.10
			289	11.75	251.0	11.80	10,260	130.0	15.10

Westinghouse Gas Engines, Continued.

Comparison of Steam and Gas Engine Plants.

As for efficiency and economy, the apparent advantage in favor of the gas engine is very great. If fuel alone were the measure of saving, even the most improved type of steam engine would not be a commercial proposition in competition with the modern gas engine. There are many factors entering into a comparison that cannot be elaborated upon within the scope of this article, however, and, therefore, I simply submit the following comparative statements of the performance of both steam and gas engine plants from the simple standpoint of efficiency and economy of fuel.

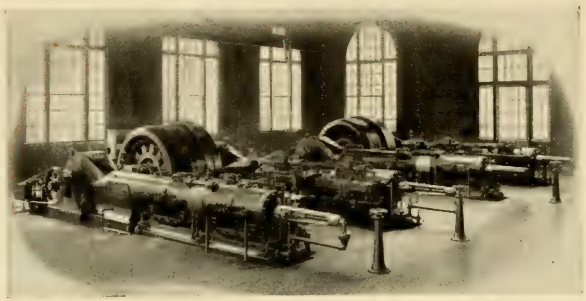
Steam Engine Plants.

(1). *Simple Non-Condensing Engine.*
Steam pressure, 100 lbs. per sq. in. guage.
Steam Consumption, 28 lbs. per I. H. P. per hour.
Mechanical Efficiency of Engine, 92%.
Losses in steam pipe, 5%.
Evaporative efficiency of boilers, 70%.
Feed water temperature, 210 degrees Fahrenheit.
Total heat in one pound of steam, 1217 B. T. U.
Heat added to water to generate 1 lb. of steam, 1007 B.T.U.
Heat consumption of plant per B. H. P. per hour, 46,000 B. T. U.
Thermal Efficiency of Plant, 5.5 per cent.
(2). *Compound Condensing Engine.* Steam pressure, 150 lbs. per sq. in. gauge.
Steam consumption, 15 lbs. per I. H. P. per hour.
Mechanical efficiency of engine with condensing outfit, 90%.
Losses in steam pipe, 5%.
Evaporative efficiency of boilers, 70%.
Feed water temperature, 180 degrees Fahrenheit.
Total heat in 1 lb. of steam, 1225 B. T. U.
Heat added to water to generate 1 lb. of steam, 1045 B. T. U.
Heat consumption of plant per B. H. P. per hour, 26,200 B. T. U.
Thermal Efficiency of Plant, 9.7 per cent.

Gas Engine Plants.

(3). *Operating with Producer Gases.* Heat consumption per B. H. P. per hour B. T. U. 11,000.
Efficiency of gas producer, 80%.
Heat consumption of plant per B. H. P. per hour, 13,750 B. T. U.
Thermal efficiency of plant, 18.5 per cent.
(4). *Operating with waste gases from Blast Furnace or Coke Retorts.*. Heat consumption per Brake Horse Power per hour, 11,000 B. T. U.
Losses in gas cleaning, etc., 8%.
Heat consumption of plant per Brake Horse Power per

Westinghouse Gas Engines, Concluded.



(The above cut is published simply as an object lesson. It shows two 2,000 H. P. alternating current parallel operated units that the Westinghouse Company installed several years ago for furnishing light and power. The engines are of the double crank, double acting, tandem cylinder type and are of the first design brought out by the Westinghouse Company for heavy work. By comparing this cut with the one at the top of page 943, it will be readily seen that there is a great improvement in design. Still this cut is interesting at this time and place because of the fact of its showing that this class of work is not new with the Westinghouse Company, but that they have had large units operating alternators in parallel for a long time.)

---

hour, 11,950 B. T. U.

Thermal efficiency of plant, 21.3 per cent.

Summary.

In cases where coal is used, the coal consumption per effective horse power would naturally be, for the same class of coal, in direct proportion to the heat consumption of the plant, and assuming coal having about a heat value of 13,500 B. T. U. per pound, a plant operating 3,000 hours per annum and a consumption of say 10% additional coal for banking, etc., the coal consumption of the three types of plant first mentioned above would compare as follows:

Steam engine plant with simple non-condensing engine, 11,250 lbs. of coal per B. H. P. per annum.

Steam engine plant with compound condensing engine, 6,400 lbs. of coal per B. H. P. per annum.

Gas engine plant with producer gas, 3,050 lbs. of coal per B. H. P. per annum.

Saving in coal by gas engine over simple non-condensing engine, 8,200 lbs. per B. H. P. per annum, or 73 per cent.

Saving in coal by gas engine over compound condensing steam engine, 3,350 lbs. per B. H. P. per annum, or 52 per cent.

From the above figures may be readily calculated the fuel saving effected by the use of a gas engine. In almost every case this saving will pay a profit upon the additional investment necessitated by the installation of a gas engine plant, even after allowing for a higher interest, depreciation and labor account.

CENTRIFUGAL PUMPS.

For All Kinds of Service, but in Mill Work Especially Adapted to Use in Connection With Condensers.

Note:—Whereas the types of condensing apparatus shown in the preceding pages have generally been shown as combined machines, a great deal of surface condensing work, especially where high vacuums are desired, calls for separate circulating and vacuum pumps; the vacuum pumps are often triplex pumps motor driven; and the circulating pumps are of the centrifugal type also motor driven. This is convenient where electric power is available, such as it naturally would be in a steam turbine plant: for other power work the pumps may be either steam or belt driven.

Centrifugal pumps are divided into three classes, viz: Conoidal, Volute and Turbine.

The Conoidal Centrifugals are designed especially for low lifts and large deliveries and are adapted to irrigation work, the handling of sewage and similar purposes. They are comparatively inexpensive and operate at high rotative speeds. They are especially designed for heads up to 30 feet.

The Volute Centrifugals are built for medium lifts, but for all capacities. Since they run at moderate speeds, diffusion vanes are not needed, but the volute casing has been carefully designed to obtain high efficiency and 86% has been shown under test. These pumps are recommended for heads up to 70 feet.

The Turbine Centrifugals are suited to very high lifts, even exceeding 2,000 feet.

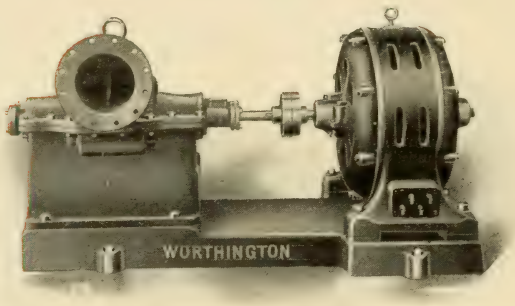
Conservatively stated, turbine pumps having a discharge of 3 inches and less may be assumed to be good to work against 100 feet head per stage; and those over 3 inches for 125 feet per stage.

On this basis a 3 inch two-stage pump would be good for 200 feet; a 3 inch three-stage for 300 feet; a 4 inch four-stage for 500 feet, etc.

Standard Rating of Worthington Centrifugal Pumps.

Size, in Inches.	U. S. Gallons per Minute.	Size, in Inches.	U. S. Gallons per Minute.
1½	60	8	1800
2	100	10	2800
2½	150	12	4000
3	250	14	5500
4	450	16	7500
5	700	18	9500
6	1000	20	12000
		24	18000

CONOIDAL CENTRIFUGAL PUMP.



10″ Conoidal Pump.

(Direct-connected to an induction motor. Used for supplying cooling water to a surface condenser.)

This pump has been designed to meet the demand for a thoroughly well-built, compact machine for direct connection to electric or other high-speed motors. The general appearance is somewhat different from the ordinary centrifugal, due partly to the widening of the pump chamber to admit a special form of impeller consisting of a double, conical-shaped core, on which radial vanes are cast or mounted.

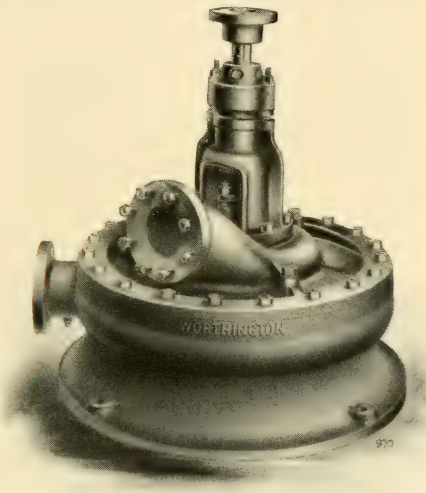
VOLUTE CENTRIFUGAL PUMPS.

This type of centrifugal was one of the first to be developed and, with a few changes, has to the present day been adopted by most manufacturers as the standard.

The new Worthington volute pumps embody important improvements which enable them to work efficiently up to a head of 85 feet, and they have shown under test an economy of 86%. It has been found possible to obtain a high efficiency at any head between 15 feet and 65 feet without making the pumps either especially large or expensive.

In the volute pump, because of the moderate heads and velocities, diffusion-vanes may be dispensed with. The impeller is of the triple-vane type employed in the turbine pump.

WORTHINGTON TURBINE CENTRIFUGAL PUMPS.

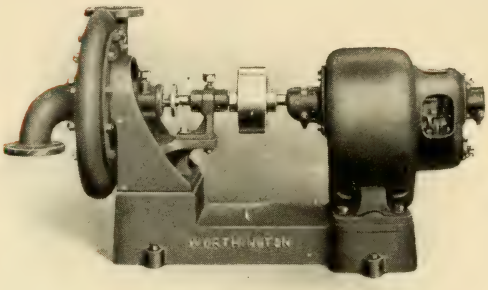


4″ Single-Stage Vertical, Hot-Well Turbine Pump.

(Designed for direct connection to a vertical-shaft induction motor. Capacity, 300 gallons per minute against 70 feet head. This pump is employed to remove the water of condensation from a surface condenser and takes its suction under a vacuum of 28 inches.)

In the Worthington turbine pump the diffusion vanes, which form the distinguishing feature, take the place of the whirlpool chamber usual in other forms of centrifugal pumps, and assist in bringing the water to rest without internal commotion or shock. They correspond in function to the guide vanes of turbine water-wheels. One of the difficulties presented by high-lift centrifugal pumps has been the great peripheral speed required when only a single impeller is employed. This has been overcome in the Worthington multi-stage turbine pump by mounting a number of discs or impellers, each operating in a separate chamber, upon a single shaft and passing the water through the impeller chambers in succession. The lift can thus be multiplied three, four or five times, while the number of revolutions is kept within such bounds that it is possible to connect the pump directly to a steam engine or an electric motor.

Centrifugal Pumps. Continued.



Direct Connection to Electric Motors.—The electric motor enters a widened field of usefulness through the improvement of the centrifugal pump, as the two are perfectly adaptable to each other. A motor-driven pump set is very similar in operation to a motor-generator set, the output being water under pressure in the first case, instead of electric current. At constant speed the power and output are inversely proportional to the resistance to flow, and the efficiency is practically constant within wide limits.

The operation of pumps by electric motors is often a complicated problem. First of all, there are very few places where a constant delivery of water is wanted. To vary the quantity, then, it is necessary either to vary the speed of the motor or to provide a complicated and unsatisfactory system of by-pass valves, both of which methods are in general wasteful of power and unsatisfactory in operation. In some cases automatic devices are installed, intended to stop and start the motor whenever the pressure falls short of or exceeds certain limits. In the centrifugal pump, on the other hand, the flow is automatically regulated by the pressure and the pump may be so designed that this regulation will be very close and exact.

The centrifugal pump is noiseless and the speed can be made to fit the requirements of the motor. There is no shock or pulsation in the piping and nothing disastrous happens if the discharge is stopped.

In the case of alternating current motors the centrifugal pump has a decided advantage in that the starting torque is very low, especially if the discharge valve is closed.

Centrifugal Pumps, Concluded.

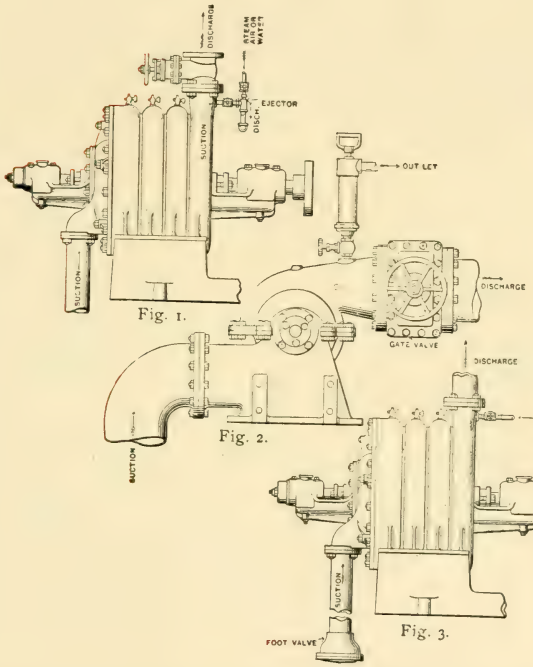


Fig. 1.

Fig. 2.

Fig. 3.

Method of Starting Centrifugal Pumps.—Massive foundations are not necessary, but the pump should be so placed that perfect alignment is assured.

Figure 1 illustrates a multi-stage turbine pump with ejector for priming. The ejector is connected to the highest point on the pump casing, and either steam, air or water under pressure may be employed to produce a vacuum.

Figure 2 shows an auxiliary hand pump mounted on top of the discharge casing. When the pump is ready to start, the gate valve on the discharge is closed and by operating the hand pump a vacuum is produced and water drawn in, filling the suction pipe and casing.

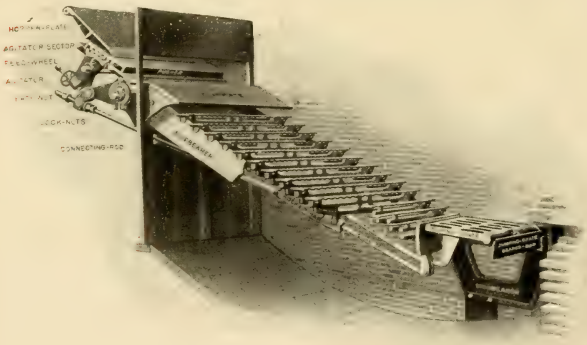
The method of priming shown in figure 3 may be resorted to where a foot valve is used on the suction pipe. Water is allowed to run into the pump until it reaches the discharge flange, when the supply is shut off, and the pump may be started.

After the pump has been properly primed, it should be started before the gate valve on the discharge is opened. When full speed is reached, the discharge gate may be slowly opened, and the pump will perform its work in a proper manner.

RONEY MECHANICAL STOKERS.

The use of mechanical stokers in the mill trade of the South has been very unsatisfactory, there being, indeed, but few plants that have not been discarded. On the face of it, it appeared to most mill engineers and mill men generally that stokers had best be let alone in this particular line of industry. I myself shared this view, and have advised against their use for a number of years. My attention, however, has recently been called to the fact that while it is true the majority of stoker plants have been unsatisfactory, that most of the few which have given satisfaction are Roney mechanical stokers, built by the Westinghouse Machine Company.

The following cuts, with brief explanations thereto, explain the construction and application of these machines.

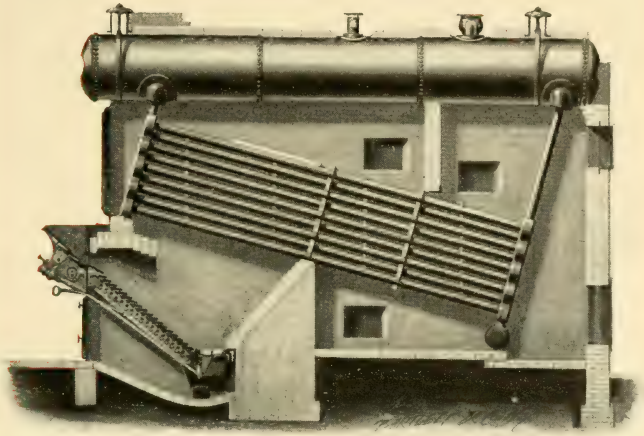


(Sectional Perspective of the Roney Mechanical Stoker.)

Its simplicity of construction will be easily understood from the above cut. It consists of a hopper for receiving the coal, a set of rocking stepped grate-bars, inclined at a proper angle from the horizontal, and a dumping-grate at the bottom of the incline for receiving and discharging the ash and clinker. The dumping-grate is divided into several parts for convenience in handling.

The coal is fed on to the inclined grate from the "hopper" by a reciprocating "pusher", which is actuated by the "agitator" and "agitator-sector" which receive their motion through the "eccentric" from a shaft attached to the stoker front, under the "hopper." The grate-bars rock through an arc of 30 degrees, assuming alternately the "stepped" and

Roney Mechanical Stokers, Continued.



(The Roney Mechanical Stoker Applied to a Babcock & Wilcox Boiler.)

the "inclined position." The grate-bars receive their motion from the "rocker-bar" and "connecting-rod," and these, with the "pusher," are actuated by the "agitator." The range of motion of the "pusher" is regulated by the "feed-wheel" from no stroke to full stroke, and the amount of coal supplied to the furnace varied according to the demand for steam. The motion of the grate-bars is similarly controlled by the position of the "sheath-nut" and "lock-nuts" on the "connecting-rod." Each grate-bar is composed of two parts, a vertical "web" provided with trunnions at each end, which rest in seats in the "side-bearers," and a sectional corrugated "fuel-plate," which bolts to the web. These "fuel-plates" carry the bed of burning coal, and being wearing parts, are made detachable, thus reducing cost of repairs to a minimum. The "webs" are perforated with longitudinal slots so placed that the condition of the fire can be seen at all times without opening doors, and free access had to all parts of the grate to assist, when necessary, the removal of clinker. These slots also serve an important purpose in furnishing an abundant supply of air for combustion. The stoker is fitted with what is termed a "guard," which in the "raised position" prevents the coal from sliding when the "dumping-grate" is dropped to discharge the accumulated ash and clinker. On raising the "dumping-grate" again to its normal position, the "guard" is dropped.

Roney Mechanical Stokers, Concluded.

(Boiler Plant Equipped with Roney Mechanical Stokers.)

The Saving in Labor. Ordinarily one man with the stokers will do the work of two or more hand-firing, and with less exertion. The greatest labor saving, however, is gained when the boiler plant is large enough to warrant the use of coal and ash-handling machinery. With such an equipment the labor item can be reduced to one-third, and in very large plants to one-fifth that of a hand-fired plant of the same size. Furthermore, by the use of this stoker one intelligent foreman in the boiler room is able to control the labor of many inferior firemen and obtain a uniformity and efficiency of operation impossible with hand-firing.

CRAMER SYSTEM OF AIR CONDITIONING.

Humidity and Temperature Automatically and Positively Regulated According to Any Predetermined Scale.

Owing to the delay in getting out this second volume, a large part of which was ready for the printer in 1904, I am able to present something new in the way of equipment for cotton mills that is, I believe, of vast importance to cotton manufacturers.

On page 370 I refer to a new system of humidification that I expected to place on the market within the next year or so, —an "apparatus that will not only automatically and positively regulate humidity but also temperature," and "one embodying the feature of ventilation, which feature will be continuous, even though the humidity feature were automatically stopped."

Not only has that expectation since been attained, but it has been exceeded, as will be shown by the brief description following.

Features Peculiar to This System.

(1). The air in a mill or factory is positively and automatically regulated the year round, both as to temperature and humidity, to conform to any predetermined scale desired, even though such scale be a varying one,—with the only exceptions that, though the temperature of summer heat is materially reduced, it can not be entirely controlled, and that though excessive humidity is materially reduced, it also can not be brought down always to as low a point as might be strictly desirable.

(2). Humidity in a mill or other room is rapidly raised to a predetermined point and maintained.

(3). Excessive humidity, such as in dog days, is reduced to a condition not greatly in excess of normal.

(4). Complete and satisfactory ventilation is provided, the air being tempered both as to heat and moisture as it enters and in any desired quantities. The English Factories Act requires 600 cubic feet per hour per operative, which can be increased to 1,000, 1,200, or more feet if desired.

(5). Ventilation can be partly or wholly stopped without discontinuing humidification.

(6). Humidification is automatically stopped when the desired percentage has been obtained without discontinuing the ventilation.

(7). Air cleansing and purifying is positively and effectually accomplished on a predetermined basis of treating all the air in the room as often as may be desired,—say every thirty, sixty, or ninety minutes.

(8). Air cleansing is not materially interfered with by discontinuing either the humidifying or the ventilating features, but continues all day uninterruptedly.

(9). Automatic regulation is accomplished by apparatus which is extremely simple and durable, and which may be installed at moderate cost.

Cramer System of Air Conditioning, Continued.

(10). The automatic regulator itself may be technically termed a combined hygrostat and thermostat, as it serves in a dual capacity as the controlling element of both the humidifying and the heating systems.

(11). The automatic regulator involves the well-known principles of the wet and dry bulb thermometer type of hygrometer, which is recognized the world over as the only type of standard instrument for that purpose. Many attempts have been made to devise instruments that would take the place of this wet and dry bulb type of hygrometer, but they have all been ignominious failures,—they generally depending upon the behavior or misbehavior of vegetable or animal fibers or materials under different atmospheric conditions. For convenience I refer to this type of hygrometer as the mechanical type. Their lack of trustworthiness is due to two causes: The first being that humidity affects them to a different degree at different temperatures; and the second is the susceptibility of the surface pores of the sensitive substances to being choked up by dust, lint, etc., etc., a thin coating of which causes the indications to become both sluggish and erratic.

(12). The energy required for automatic regulation is both electrical and pneumatic.

The electric current required is insignificant, being furnished by a small dynamo or generator of low voltage, and ranging from 1-4 H. P. in small mills to 1 H. P. in large mills. It is therefore unfailing, and is not dependent upon the vagaries and uncertainties of batteries.

The pneumatic energy, or air pressure, required is furnished by an exceedingly small air compressor, the power required to drive which is even less than that required to drive the electric generator, and will not average all day long in a large mill 1-8 H. P.,—the consumption of air being only intermittent and in exceedingly small quantities of a foot or two at a time.

(13). The automatic regulation is accomplished by the co-ordination of the following elements:

The automatic regulator electrically connected with a source of electricity (the generator) to electrically operated valves, one in connection with the humidifying system and one or more in connection with the heating system in each room; each electrically operated valve is in turn connected pneumatically to main shut-off valves in either the heating or the humidifying systems, as the case may be. In the case of direct steam or hot water heating, one electrical valve can act as a controller for two or more cut-off or main valves. And similarly, in the case of a fan or blower system of heating, one supplemental valve can close any number of dampers,—the dampers can even be closed in sections alternately, or all at once, as may be desired.

(14). To use a term by which the "heads," or parts of the apparatus specifically concerned with the actual operation of humidifying are concerned, the type of "head" or "humidifier" itself comprising a part of my system, embodies, I believe, the best features of the systems heretofore in vogue, combined with certain other new and novel features which have been evolved not only in years of experimenting with humidifiers themselves, but also in studying the requirements of automatic regulation.

I have not the space to discuss the details of these "humidifiers" in this volume, but will take them up in connecton with the general subject of Mill Architecture and Mill Engineering in Vol. III., under a heading to be designated "Apparatus for Air Conditioning," which, as already indicated, covers ventilation, heating, humidification, and air cleansing.

Important.

While the automatic system of regulation, as would naturally be expected, works out best with my own specific type of air conditioner especially designed for that purpose, it is by

Cramer System of Air Conditioning, Concluded.

no means to be considered as applicable only to new work involving their use. On the contrary, it can be used to automatically regulate any other known existing type of humidifying apparatus now installed in cotton mills, whether of the atomizer or spray head type, or in any other system of natural or forced evaporation more or less akin to my "air conditioner." That the work done in mills at present equipped with humidifying systems can be vastly improved by installing this system of automatic regulation, is too obvious to a practical mill man to require further elaboration.

WESTINGHOUSE NEW TYPE CCL POLYPHASE INDUCTION MOTORS.

This latest motor product of the Westinghouse Company is specially designed for the smaller sizes of mill work. In this appendix it is possible to devote only one page to it, with the necessary data in the way of speeds and sizes of pulleys.

Horse Power.	Full Load Speed.	Pulleys	
		Diameter.	Face
Voltage 100 and 200.			
½	1700	3″	1 3/16″
Voltage 100, 200 and 400.			
1	1700	3½″	2″
2	1700	4″	2½″
3	1700	5″	3″
5	1700	5″	3″
Voltage 200 and 400.			
7½	1120	7″	4″
10	1120	8″	4″
15	1120	9″	5″
20	1120	11″	5″
20	850	14″	8″
30	1120	12″	6″
30	850	15″	6″
40	850	15″	8″
50	850	17″	10″
75	690	21″	12″

WESTINGHOUSE NEW TYPE CX POLYPHASE INDUCTION MOTORS.

In this appendix it is possible to devote only one page to this new type of motor, and therefore simply to call attention to it.

These machines are very much like their prototypes, the Type C motors. In fact, it may be really said to be a redesigned skeleton form of the Type C motor.

Table of Sizes.

Horse Power	Full Load Speeds	Pulleys	
		Diameter	Face
Voltage 100-200.			
1¼	1700	5	3
2½	1700	5	3
Voltage 100-200-400.			
4	1700	5	4
Voltage 200-400.			
7	1120	9	5
10	1120	9	5
10	840	12	5
15	1120	9	5
15	840	14	6
20	1120	10	8½
20	840	14½	8
25	1120	10	8½
25	840	16	8
40	850	19	10
50	850	19	10
65	850	21	12
100	690	26	15
140	580	32	18
200	580	33	18
250	580	33	24
Voltage 1000-2000.			
65	850		
100	690		
140	580		
200	580		
250	580		

The motors will develop their rated H. P. continuously with rise of temperature not exceeding 40 degrees Centigrade above the surrounding atmosphere, and 25 per cent. overload for two hours with rise of temperature not exceeding 55 degrees Centigrade above the surrounding atmosphere.

GENERAL ELECTRIC, NEW SKELETON TYPE, INDUCTION MOTORS.

This new line of induction motors which the General Electric Company are now bringing out, is a modified type of both the Form K and Form L, the peculiarity of designs being the skeleton type of frame. These are the important points in which these motors differ from their prototypes, though there are other details of difference which it is unnecessary to enter into in the limited scope of this article.

Table of Sizes.

Horse Power	Synchronous Speeds	Pulleys	
		Diameter	Face
1	1800	4	2
2	1800	4½	2½
3	1800	4½	2½
5	1800	4½	4
7½	1800	4½	4
7½	1200	8	5
10	1200	8	6
15	1200	10	6
20	1200	10	7
25	900	13	7
35	900	13	9
550 Volts and Under.			
50A	900	13	11
75A	720	19	15
100A	720	21	15
150A	600	29	18
200A	600	32	20
2080 Volts.			
30A	900	13	9
40A	900	13	11
60A	720	19	15
85A	720	21	15
125A	600	29	18
175A	600	32	20

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